MACHINIST'S MATE 2

NAVY TRAINING COURSES

NAVPERS 10523

MACHINIST'S MATE 2

Prepared by U. S.

BUREAU OF NAVAL PERSONNEL

NAVY TRAINING COURSES

NAVPERS 10523

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ACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
SERVICE	4 mos. service—or completion of recruit training.	6 mos. as E–2 or 8 mos. total service.	6 mos. as E–3 or 14 mos. total service.	12 mos. as E–4.	12 mos. as E–5; total service at least 36 mos.	36 mos. as E–6.
SCHOOL	Recruit Training.		Class A for PR3, PRS3.		Class B for MN1.	Class B for AGCA, MNCA, MUCA.
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.			
PRACTICAL FACTORS	Locally prepared check-offs.	Records of Practical Factors, NavPers 760, must be completed for E–3 and all PO advancements.				
PERFORMANCE TEST			Specified ratings must complete applicable performance tests before taking examinations.			
EXAMINATIONS	Locally prepared tests.		Service-wide examinations required for all PO advancements.			
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Required for E–3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed.				
AUTHORIZATION	Commanding Officer		U. S. Naval Examining Center			BuPers
	TARS are advanced to fill vacancies and must be approved by district commandants or CNARESTRA.					

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

INACTIVE DUTY ADVANCEMENT REQUIREMENTS

REQUIREMENTS*	FOR THESE DRILLS PER YEAR	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7A
TOTAL TIME IN GRADE	24 OR 48 12 NON-DRILLING	9 mos. 9 mos. 12 mos.	9 mos. 15 mos. 24 mos.	15 mos. 21 mos. 24 mos.	18 mos. 24 mos. 36 mos.	24 mos. 36 mos. 48 mos.	36 mos. 42 mos. 48 mos.
DRILLS ATTENDED IN GRADE#	48 24 12	27 16 8	27 16 13	45 27 18	54 32 20	72 42 32	108 64 38
TOTAL TRAINING DUTY IN GRADE#	24 OR 48 12 NON-DRILLING	14 days 14 days None	14 days 14 days None	14 days 14 days 14 days	14 days 28 days 14 days	28 days 42 days 28 days	42 days 42 days 28 days
PERFORMANCE TESTS				Specific ratings must complete applicable performance tests before taking examination.			
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)		Record of Practical Factors, NavPers 1316, must be completed for all advancements.					
NAVY TRAINING COURSE (INCLUDING MILITARY REQUIREMENTS)		Completion of applicable course or courses must be entered in service record.					
EXAMINATION		Standard exams are used where available, otherwise locally prepared exams are used.					
AUTHORIZATION		District commandant or CNARESTRA					BuPers

*Recommendation of petty officers, officers and approval by commanding officer required for all advancements.

#Active duty periods may be substituted for drills and training duty.

THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

PREFACE

This training course has been prepared for enlisted men of the Navy and of the Naval Reserve who are preparing for advancement to Machinist's Mate 2. Study of this training course should be combined with practical experience, with review of other applicable Navy training courses, and with study of manufacturers' technical manuals, BuShips *Manual,* and other pertinent material.

Qualifications for advancement to Machinist's Mate 2 are listed in Appendix II of this publication. Since the examinations for advancement are based upon these qualifications, it is suggested that the reader refer to them frequently for guidance.

In the first chapter of this training course the specific duties and responsibilities of the Machinist's Mate 2 are discussed; in addition, chapter 1 contains information concerning the general scope of the Machinist's Mate rating. The remainder of this training course contains information dealing primarily with the systems and equipment which will be operated and maintained by the Machinist's Mate 2.

As one of the Navy Training Courses, *Machinist's Mate 2* has been prepared by the United States Navy Training Publications Center for the Bureau of Naval Personnel. Technical assistance has been furnished by the Bureau of Ships and by the United States Naval School, Machinist's Mates, Class A, United States Naval Training Center, Great Lakes, Ill.

STUDY GUIDE

The accompanying table indicates the chapters of this training course which will be particularly helpful to you as you study for advancement in rating. To use the table, select the column that applies to your rating. Chapters which are not applicable to a particular rating are marked NA. Chapters applicable to a particular rating are marked with an asterisk (*). In some cases, where a chapter is identified by the symbol AP*, only a portion of a chapter is applicable to a particular rating; the applicable portion of such a chapter may be determined by a review of the qualifications for advancement, which are listed in appendix II of this training course. Study the indicated chapters; they include information related to the qualifications for advancement.

If you are advancing in the general service rating, you should study all chapters of this training course. If you are in the Naval Reserve or are advancing in an emergency service rating for some other reason, study the chapters indicated in the column headed by your particular emergency service rating: MML (General Machinist's Mates), MMR (Refrigeration Mechanics), or MMG (Gas Generating Mechanics). For example: If, as a member of the Naval Reserve, studying for advancement to MMR2, you should study the chapters identified in the column marked MMR. That column reveals that you should study chapters 1 and 8, and the applicable portions of chapters 3, 4, 5, 6 and 7.

Even though you are advancing in one of the emergency service ratings, it will be advantageous to you to have a general knowledge of the requirements for the general service rating. It is recommended, therefore, that you study all chapters of this training course, in order to gain a more complete understanding of the require-

Chapter	MM	MML	MMR	MMG
1 -----------	(*)	(*)	(*)	(*)
2 -----------	(*)	(*)	NA	NA
3 -----------	(*)	(*)	AP*	AP*
4 -----------	(*)	(*)	AP*	AP*
5 -----------	(*)	NA	AP*	AP*
6 -----------	(*)	(*)	AP*	AP*
7 -----------	(*)	(*)	AP*	AP*
8 -----------	(*)	(*)	(*)	(*)
9 -----------	(*)	(*)	NA	NA
10 -----------	(*)	(*)	NA	NA

* Entire chapter should be studied.
NA Not applicable.
AP* Applicable portion of chapter should be studied.

ments for the Machinist's Mate who is advancing in the general service rating.

Navy training courses, for the most part, are prepared so as to include information related to all qualifications for specified rates of general service ratings. In most instances, the same information will be equally applicable to the corresponding rates in the emergency ratings. In some cases, however, a qualification which is applicable to a particular rate in the general service rating may apply to a lower or higher rate in one or more of the emergency service ratings. This is true of qualifications 102.26, 201.11a, 202.3o, 202.3p, and 202.6 in the Machinist's Mate rating. In the general service rating, first class petty officers are held responsible for having a knowledge of these qualifications; however, second class

petty officers of the MMR and MMG emergency ratings are held responsible for the qualifications listed. Information related to these particular qualifications is included in the Navy training course, *Machinist's Mate 1 & C,* NavPers 10525.

Still another source of information will have to be used by those advancing in the MMG emergency service rating. Information related to those qualifications which deal specifically with industrial gases is not included in this training course; such information is provided in the Navy training course, *Field Manufacture of Industrial Gases,* NavPers 10078. The MMG studying for advancement to second class will, therefore, need copies of *Field Manufacture of Industrial Gases,* NavPers 10078, and *Machinist's Mate 1 & C,* NavPers 10525, in addition to a copy of this training course. See your Information and Education Officer for copies of the necessary training courses.

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CREDITS

All illustrations in *Machinist's Mate 2* are official United States Navy material with exception of the copyrighted illustrations designated below:

Source	Figures
United States Naval Institute	3–1, 3–2, 3–3, 3–4, 3–5, 3–6, 3–7, 3–8, 3–10, 3–11, 3–22A, 3–23, 3–24, 3–25, 4–3, 4–9.
Theo. Audel and Company	4–4.

MACHINIST'S MATE 2

READING LIST

NAVY TRAINING COURSES

Basic Hand Tool Skills, NavPers 10085 (Chapters 1–6, 10)
Blueprint Reading and Sketching, NavPers 10077–A (Metal working skills only)

OTHER NAVY PUBLICATIONS

BuShips *Manual*, Chapters 4, Section I; 6, Sections II, III, IV; 43; 46; 49, Sections II, III; 58, Section I; 59, Sections II, III

USAFI TEXTS

United States Armed Forces Institute (USAFI) courses for additional reading and study are available through your Information and Education Officer.* A partial list of those courses applicable to the Machinist's Mate rating follows:

Correspondence Courses

Number	Title
CB 856	*Shop Mathematics I*
CB 857	*Shop Mathematics II*
CC 936	*Refrigeration*

Self-Teaching

MB 856	*Shop Mathematics I*
MB 857	*Shop Mathematics II*
MC 936	*Refrigeration*

* "Members of the United States Armed Forces Reserve components, when on active duty, are eligible to enroll for USAFI courses, services, and materials if the orders calling them to active duty specify a period of 120 days or more, regardless of the time specified in the active duty orders."

CHAPTER 1

PREPARING FOR ADVANCEMENT TO MM2

The duties and responsibilities which you have learned to assume as a Fireman and as an MM3 represent but a small portion of those which you must be able to assume as you advance in the Machinist's Mate rating. From your experience as an MM3, you know that the responsibilities of Machinist's Mates include the operation, maintenance, and repair of steam propulsion and auxiliary equipment (steam propulsion machinery, shafts, evaporators, pumps, oil purifiers, and heat exchangers); and that Machinist's Mates also know how to maintain and repair outside machinery (steering engines, elevators and other hydraulic equipment, food-preparation equipment and related utility equipment) and refrigeration and air conditioning equipment. In order to perform their duties efficiently, Machinist's Mates must have a thorough understanding of the equipment they are responsible for operating and maintaining; in addition, they must possess a general knowledge of the operation of the division and of the ship to which they are assigned. In brief, these are the over-all requirements of the Machinist's Mate rating.

DUTIES OF THE MM2

Careful study of the quals for MM2 will show that you must do a variety of tasks. For example, you will be required to know how to renew ram packing on hydraulic

steering gears and elevators; you will make certain repairs such as repacking high-pressure valves and refacing valve seats and disks; you will be responsible for the operation of high- and low-pressure turbines and other propulsion and auxiliary machinery; and you will be required to know the procedures to be followed when removing scale from evaporator tubes, and when spotting-in slide valves on the steam chest of reciprocating pumps. Above all, you will be required to know the procedures to be followed when certain casualties occur, such as the loss of main feed booster pump pressure or a lubricating oil leak in the engineroom.

GENERAL AND EMERGENCY SERVICE RATINGS

The Machinist's Mate rating has a dual breakdown in classification—the general service and the emergency service ratings.

The GENERAL SERVICE RATING for Machinist's Mates is MM. This rating, which applies during normal peacetime operations, covers the entire field of the Machinist's Mate responsibilities since the training mission of the peacetime Navy is to produce broadly qualified, versatile personnel who, in time of emergency, can be advanced to positions of greater responsibility and authority.

During a national emergency, the Machinist's Mate rating is divided into three specialized groups called EMERGENCY SERVICE RATINGS: Machinist's Mates L (General Machinist's Mates), Machinist's Mates R (Refrigeration Mechanics), and Machinist's Mates G (Gas Generating Mechanics). The duties in each group are based primarily on the type of equipment with which the particular group must be familiar.

Upon the Navy's return to a peacetime organization after a national emergency, regular Navy personnel who are in emergency service ratings will be required to qualify for the appropriate general service rating. Members of the Naval Reserve, however, will continue to be carried in their emergency service ratings. A Reserve

Machinist's Mate who wishes to ship over to the regular Navy in peacetime must meet all the requirements of the appropriate rate of the general service Machinist's Mate rating.

QUALIFICATIONS FOR ADVANCEMENT IN RATING

In order to fully understand the requirements for advancement to MM2, you must make a careful study of the qualifications for the rate; these are listed in the *Manual of Qualifications for Advancement in Rating,* NavPers 18068, Revised ("Quals Manual"). That portion of the *Manual* which deals with Machinist's Mate qualifications is given in appendix II of this training course. The qualifications for MM2 (to which periodic changes are made) have been used as a guide in the preparation of this training course. In addition, the "quals" are used as a guide by those who prepare the service-wide competitive examinations for advancement. Therefore, it is important for you to refer to the latest revision of the "Quals Manual" as well as to the back of this training course.

As you study these qualifications for advancement, remember that the qualifications listed represent only the MINIMUM requirements for each rate. Compare the required qualifications with those you now possess. If you doubt your ability to meet any of the requirements, study the appropriate Navy training courses, manufacturers' technical manuals, applicable chapters of BuShips *Manual,* and any other available reference material which will be of value to you.

PREPARING FOR ADVANCEMENT

As you prepare for advancement in rating, it is best to learn all you can by actually working with the ship's machinery and equipment. Instruction books, manuals, and illustrations cannot take the place of the "know-how" that you acquire by practical experience. If you are required to possess a working knowledge of any machines

or equipment not installed on your ship, arrange to observe and study these machines on another ship, if possible.

Practical experience, however, does not provide all that is necessary for advancement. Although much "know-how" is required in the engineroom, a great deal of "know-why" is also necessary. In general, an understanding of the principles of operation of a machine, or unit, can best be obtained by reading and studying. Your ability to operate, maintain, and repair machinery will be increased if you know why the machinery operates the way it does. In addition, you will be able to determine the causes of faulty operation. A man who only knows HOW to do something is not likely to be as useful as one who knows how to do it and WHY it should be done that way. Therefore, in addition to learning all you can from practical experience, you must become familiar with the available sources of information which are applicable to your rating. Some sources of information are listed later in the chapter.

Before you will be allowed to take the examination for MM2, you will need the recommendation of your commanding officer. To qualify for this recommendation you must not only demonstrate your ability to perform the specified professional and military jobs satisfactorily but you must also demonstrate, by your day-to-day performance of assigned duties, your fitness for carrying out the military and technical responsibilities of the higher rate.

ADDITIONAL RESPONSIBILITIES

Before you can advance in rating you must meet certain military and professional requirements. As an MM3, you have mastered basic skills, you became familiar with the terminology applicable to propulsion machinery and other equipment, and you learned to answer many technical questions asked by lower rated men. Along with this increase in knowledge, you gradually assumed greater responsibilities. The rate for which you

are now preparing, however, requires still greater knowledge and skill, a willingness to assume even greater responsibilities, and an increased ability to lead men.

Every petty officer must be a technical specialist in his own field. As you advance in rating, however, it will become increasingly important for you to understand the duties and responsibilities of men in related ratings, and to understand how the entire Engineering Department functions. You must learn to know what work is done, and what equipment is used by personnel of other Engineering and Hull group ratings. (The eleven other ratings of the Engineering and Hull group are: Engineman, Machinery Repairman, Boilermaker, Boilerman, Electrician's Mate, I. C. Electrician, Metalsmith, Shipfitter, Damage Controlman, Patternmaker, and Molder.) Although it is true that many maintenance and repair jobs can be properly handled within your own division, some jobs will require skills and equipment found only in another division. Therefore, you must learn to work with the rest of the Engineering Department; and to utilize, when necessary, the skills and technical knowledge of men in the ratings mentioned above.

Military Duties

Military requirements are those general requirements, such as watch standing, first aid, and military conduct, which apply in greater or lesser degree, to all enlisted personnel. As you advance in the Machinist's Mate rating, your military duties will become more important. In addition to becoming a specialist in an occupational group, you will have an increasing responsibility for showing other men what to do and how to do the task, and for checking their work. You will be expected to provide the supervision and instruction which those men need in order to advance in their rating. Therefore, as a petty officer you are training to become a leader as well as a technical specialist.

A detailed consideration of the military requirements

for the MM2 is beyond the scope of this training course. The military requirements for enlisted personnel are published, however, as part of the "Quals Manual." They are discussed in the *Military Requirements for Petty Officer 3 & 2,* NavPers 10056.

Professional Duties

The professional, or technical, qualifications are those which enlisted personnel must have to properly perform the duties of a rate within a specific rating. As you advance in your rating, it will become increasingly important for you to understand every requirement of the Machinist's Mate rating.

Appendix II of this training course lists the professional qualifications for Machinist's Mates of every rate (3, 2, 1, and C). Notice that these qualifications are divided into two principal sections: practical factors (100 series); and examination subjects (200 series). The qualifications in each of these sections are subdivided into three groups: operational; maintenance and repair; and administrative and/or clerical.

PRACTICAL FACTORS.—These factors are those qualifications which indicate jobs that a Machinist's Mate is required to DO in order to advance. The fact that you have a knowledge of such jobs and the ability to accomplish them can best be demonstrated by actually doing the jobs. The EXPERIENCE you get every day on the job will aid you in qualifying for the practical factors. (A record of practical factors, NavPers 760, is available for each General Service Rating. As proficiency in each practical factor listed is demonstrated, an entry is made in the DATE and INITIALS columns by the supervising officer.)

EXAMINATION SUBJECTS.—The qualifications which identify the subject-matter knowledge that is essential to satisfactory performance of the practical requirements, are referred to as examination subjects. The subject matter you must KNOW in order to DO a job can be

learned best by STUDY. Your knowledge of the examination subjects can be most accurately determined by written examination. It is for this reason that the examination subjects represent the professional qualifications upon which the service-wide examinations are based. Since you must have a knowledge of the examination subjects in order to satisfactorily qualify in the practical factors, it is advisable that you make a thorough review of both the practical factors and the related examination subjects when you are preparing for an examination for advancement.

SOURCES OF INFORMATION

Since this training course does not include detailed information on military requirements, and since the information it offers on professional requirements cannot be all-inclusive, you will need additional sources of information.

References on Military Requirements

The basic reference on military requirements is the *Military Requirements for Petty Officer 3 & 2,* NavPers 10056. A knowledge of the material contained in this book is mandatory for all petty officers of all ratings. Additional information on all military requirements can be obtained from other publications listed in the current edition of *Training Courses and Publications for General Service Ratings,* NavPers 10052, Revised.

References on Professional Requirements

A great deal of information which will help you meet the professional (technical) requirements for advancement is contained in the instruction books prepared by the manufacturers of the various units of machinery. In addition, BuShips *Manual* contains valuable information concerning the operation and maintenance of most of the machinery with which you will be working.

The current edition of *Training Courses and Publica-*

tions for General Service Ratings, NavPers 10052, Revised, should be consulted for references concerning the professional qualifications for advancement to MM2. This publication consists of a bibliography which is primarily used as a guide for the preparation of professional and military examinations for advancement in rating. Since this publication is revised frequently, be sure that you consult the most recent edition. Some sources for information which may be helpful to you are:

Basic Electricity, NavPers 10086
Basic Hand Tool Skills, NavPers 10085
Basic Hydraulics, NavPers 16193
Blueprint Reading and Sketching, NavPers 10077–A
Bureau of Ships Manual
Chapter 41—Main Propelling Machinery (Section I, Turbines)
Chapter 45—Lubricants and Lubrication Systems
Chapter 49—Compressed Air Plants
Chapter 50—Auxiliary Steam Turbines
Chapter 58—Distilling Plants
Chapter 59—Refrigerating Plants
Fireman, NavPers 10520–A
Machinist's Mate 3, NavPers 10522
Metalsmith 3 & 2, NavPers 10565–B
Shipfitter 3 & 2, NavPers 10592–B

Most of the publications listed above are revised at frequent intervals, in order to bring the material up-to-date. When referring to any publication, see that you are using the most recent edition available. The current *List of Training Manuals and Correspondence Courses,* NavPers 10061, Revised, contains the titles, NavPers numbers, and latest-edition dates of available Navy training courses.

EFFECTIVE SUPERVISION

There are many skilled Machinist's Mates thoroughly familiar with every phase of their specialty, who must

learn to supervise the work of others. Supervision is a job in itself and if you want to advance in your rating, you must learn how to supervise others.

When you're in charge of a detail, you'll supervise lower rated men and strikers. It will be necessary for you to assign work to these men, and to see that the work is properly completed. It is not necessary or desirable to be "breathing down a man's collar" while he is trying to perform a task, but you must be ON HAND to see that things go right and to give advice when it is needed.

Good supervision may be achieved by observing the following steps:

1. PLAN the job thoroughly, so that you know exactly WHAT is to be done, and, as far as possible, HOW you are going to meet the problems which are likely to arise. See that the required tools and spare parts are available.

2. EXPLAIN the assignment clearly enough so that the individual who is going to do the job understands just what is to be done.

3. CHECK the progress of the job, particularly in the early stages, to catch mistakes before they result in excessive loss of time, labor, and material.

4. SUGGEST methods for doing the job, but allow the man to select any method which will result in a job well done.

5. ENCOURAGE quality in all work.

6. INSPECT each job, taking care to point out methods and reasons for eliminating unsatisfactory finished products. Test the machinery after all repairs have been made.

EFFECTIVE INSTRUCTION

As you advance in your rating, one of your primary duties will be to instruct your men in the performance of both their technical and their military duties. The fundamental principles of leadership, such as "know your men" and "know how to give orders," apply to the teaching-learning situation in which you are dealing with

men. Instructing is a very complex process, and you will have to train yourself to become an effective teacher. The following suggestions will help you:

1. KNOW YOUR SUBJECT. In order to be able to explain the subject matter which you are teaching, you must be thoroughly familiar with it.

2. MAKE THE TASKS MEANINGFUL. This can be accomplished by tying new material in with what the individual already knows, and by showing him how the new material relates to his particular duties.

3. REGULATE THE SIZE OF THE TASK. No one can be expected to learn a lengthy and complicated task all at once. As an instructor, your problem is to break down such a task into parts which are meaningful units of work.

4. HAVE YOUR MEN PARTICIPATE. Watching someone do a repair job will be most helpful; however, you will not really learn how to do a job until you have actually performed it. See that your men spend as much time as possible working on a skilled task. Listen, when necessary, to explanations, and watch demonstrations.

5. REPEAT AND DRILL. Complex skills are not learned without repetition. Drill, however, should be used wisely. It should be spaced so as to avoid monotony and fatigue. Several short periods of drill, spaced over a period of time, are better than one long period.

6. USE MUCH REWARD, LITTLE PUNISHMENT. A correct response should be amply rewarded; an incorrect response is better rectified by calling attention to the right response than by punishment. In a few cases and for a few people punishment may be necessary; in general, however, praise for good work gets better results than blame for poor work.

As an instructor, you may be required to lead discussions, deliver lectures, and give demonstrations. If it is consistent with the work to be performed, keep adding new and unfamiliar tasks to the regular duties of your men. You will then have to teach the men the proper

way to perform their newly assigned duties. By this means, the men's knowledge of their trade will be broadened and your teaching ability will be improved.

A great deal of training and instruction will be accomplished while personnel are standing watch. For example, the Machinist's Mate should make certain that non-rated men are familiar with the machinery at, or adjacent to, their watch stations. The Machinist's Mate should also be prepared, at all times, to explain the operating principles of the propulsion plant to non-rated watch standers.

SCOPE OF THIS TRAINING COURSE

The purpose of this training course is to help you meet the professional (technical) qualifications for advancement to MM2. This training course contains information dealing primarily with the systems and equipment with which you will be working. This information will aid you in meeting the required practical factors, as well as the examination subjects applicable to the MM2 rate. Chapters 2 and 3 of this training course deal with engineroom operations and turbines. Chapters 4, 5, and 6 cover pumps, valves, piping, refrigeration equipment, and distilling plants. Hydraulic and pneumatic equipment, metals, and galley, laundry, and dishwashing equipment are covered in chapters 7, 8, and 9, respectively. The last chapter contains information, applicable to the MM2 rate, on engineering casualty control.

At the end of each chapter of this training course there is a quiz section. By referring to the quiz section, you will be able to check on what you have learned by studying the material in the chapter. The answers to each quiz appear in appendix I. Try to answer the questions yourself before looking at the answers in the appendix. If you cannot answer a particular question correctly, read the related subject matter again. Then, if you are still doubtful about the subject, ask a leading petty officer of your division to explain the material to you.

REWARDS OF ADVANCEMENT

As you advance in your rating, some of the rewards which you will receive are better pay and allowances, additional pay when you retire, and more respect from your superiors as well as from the men you supervise. In addition, you will learn to realize that each time you advance in rating, particularly if you DO YOUR JOB WELL AND TAKE PRIDE IN WHAT YOU DO, you are SERVING YOUR COUNTRY in a more important way. By serving your country most faithfully, you will also have the satisfaction of knowing that you are doing a good job.

QUIZ

1. During normal peacetime operations what service rating covers the entire field of Machinist's Mates responsibilities?
2. What is the training mission of the peacetime Navy?
3. Name the Machinist's Mate emergency service ratings.
4. The requirements that you must meet before you can become an MM2 are set forth in which publication?
5. The subject matter you must know in order to do a job can best be learned by what methods?
6. What is the basic reference on military requirements?
7. What precaution should be taken before you use a publication as a source of information?
8. When supervising a job, why should you check the progress in the early stages?
9. When instructing men on how to perform a given task, how can you make the task meaningful?
10. When instructing men, why are several short periods of drill, spaced over a period of time, better than one long period?

CHAPTER 2

ENGINEROOM OPERATING PROCEDURES

The construction and operating principles of main turbines and auxiliary equipment, the lubrication of engineering machinery, and the principal engineering piping systems are described in *Machinist's Mate 3,* NavPers 10522. Before you study the engineroom operating procedures and related information which follows, a review of the subjects mentioned above may prove beneficial.

You have had some experience with the machinery and systems described in the above reference; the extent of this experience will depend upon whether you are regular Navy or Reserve. From experience and study, you may be familiar with much of the information presented in this chapter; if so, this chapter will serve as a source of review information. If your experience has been limited, you will find the information in this chapter helpful as you prepare for advancement.

The information in this chapter deals primarily with operating procedures for steam-driven propulsion machinery fitted with reduction gear and motor-driven turning gear. The steam-driven propulsion installations in the Navy vary to such an extent that only general information can be provided here. Even though the information which follows can serve, at most, as a general guide the information will be helpful to you as you learn

or review the steps to be followed in operating steam-driven propulsion equipment. In addition to studying the material in this chapter, you must become thoroughly familiar with the manufacturers' technical manuals which apply specifically to each turbine and accessory unit installed on your ship, the engineroom operating standards for your ship, and the specific instructions issued by your engineer officer.

The engineroom operating procedures which follow include the steps that are representative of those to be taken in operating mechanical-geared turbine installations on ships with two enginerooms. From your experience, you are aware that Machinist's Mates of all rates may have duties related to the warming-up, operation, and securing of a steam-driven propulsion plant. Check quals 101–7 and 101–8 (Appendix II) for some of the duties which the MM2 must be qualified to perform.

NOTES: Information related to certain steps in the procedures which follow and to the operating precautions at the conclusion of this chapter is identified as (NOTE 1), (NOTE 2), etc. These numbers are for cross-reference purposes and will serve as an aid in the study of the various procedures.

PROCEDURE FOR PLACING PLANT IN READINESS FOR GETTING UNDER WAY

A general checkoff sheet or table of instructions to be followed in getting a turbine installation ready for getting under way is usually provided on each ship. These instructions and the specified times of accomplishment of various items will differ from ship to ship in accordance with the type of installation and with the instructions issued by the engineer officer. The steps included in the following list are representative of those to be taken in placing a steam-driven propulsion plant in readiness for getting under way.

Step

1. Measure clearances where indicators are installed. Enter in log. Specify that they are cold readings.
2. Note axial position of rotor by observing finger piece markings on turbine or gear shaft (see NOTE 14).
3. Back all throttle valves off seat and reseat lightly by hand.
4. Operate hand nozzles.
5. Drain water from lubricating oil and settling tanks (see NOTE 2).
6. Clean all oil and bilge strainers. Heat oil to 90° F if necessary (see NOTE 2).
7. Examine turbine sliding feet, where fitted, to see that they are free to move.
8. Ease up on stern tube glands, allowing a small amount of water to leak through the gland.
9. Start lubricating-oil pump and see that oil is delivered to all bearings. Inspect for leaks (see NOTE 2).
10. Turn rotor so that any water therein will drain out through rotor drain holes, if provided.
11. Start motor-driven turning gear (see NOTES 5 and 6).
12. Open main injection and overboard discharge valves and start circulating pumps. Vent condenser header.
13. Line up main condensate system.
14. Open manual recirculating line.
15. Start main condensate pump.
16. Line up main feed booster pump and start recirculating condensate.
17. Turn on sealing steam to glands. Start second stage of ejector and build up vacuum (see NOTES 3 and 4).
18. Open turbine drains and thoroughly drain turbine. Keep drains open until under way (see NOTE 4).
19. Test low-pressure oil alarm, if fitted (see NOTE 2).
20. Secure auxiliary condenser and cut in auxiliary exhaust steam not used elsewhere to the main condenser.
21. Open main steam bulkhead-stop bypass one turn and warm up throttle line (see NOTE 1).
22. Open bulkhead-stop bypass and drains.
23. Start main feed pump; secure auxiliary feed pump in standby condition.
24. See that self-closing valves are free to operate. Try them by hand if possible.
25. Do not circulate water into oil cooler until the specified oil temperature is reached (see NOTE 2).
26. Drain lines to whistle and siren.

27. Turn steam on whistle and siren.
28. Test engine telegraph.
29. Get permission to turn over main engine by steam.
30. Disconnect turning gear (see NOTES 5, 6, and 7).
31. Close throttle bypasses and warming up valves.
32. Take and log counter readings.
33. Turn over main engine by "spinning" (see NOTE 7).
34. Take and record turbine clearances (see NOTE 14).
35. Open bulkhead stop wide.
36. Close bulkhead-stop bypass.
37. Start first stage of air ejector and build up vacuum to maximum obtainable (see NOTES 3 and 8).
38. Report ready to engineer officer and officer of the deck (see NOTE 8).

NOTES ON PREPARATIONS FOR GETTING UNDER WAY

Preparations for getting under way consist of starting the necessary auxiliaries and warming up the main turbines. During this warming up process, the temperature of the various parts of the installation is raised from the temperature of the surrounding atmosphere to approximately that reached during the early stages of operation. While this change in temperature is taking place, the metals in the various parts of the installation expand; therefore, if inefficient operation and damage due to distortion are to be prevented, all parts of the main turbines must be heated evenly and gradually.

Before Warming Up the Turbines

A number of steps must be taken before the turbines are warmed up. These steps include warming up the main steam and throttle lines, placing the lubrication system in operation, and making proper use of the air ejectors.

WARMING UP MAIN STEAM AND THROTTLE LINES (NOTE 1).—Two methods for warming up the main steam lines and the throttle lines are permitted.

The preferred method is to warm up the main steam line to the bulkhead stop. The steam line should be

warmed up by opening the bypass valves; these valves must be opened slowly. The drains must be open; and the traps, if fitted, must be functioning properly to ensure proper drainage of the main steam line. The main steam line must be warmed up slowly to prevent leaks at the joints and must be carefully drained to preclude all danger of water hammer. After the main steam line is warmed up, build up pressure in the main throttle lines by cracking the bypass around the bulkhead stop.

The alternate method of warming up the steam and throttle lines is to crack the boiler stops and the bulkhead stop and to permit pressure to build up slowly in the lines to the main throttles.

TURBINE PLANT LUBRICATION (NOTE 2).—If you have checked quals 101–7 and 101–8 carefully, you have noted that, except for the opening and closing of specific valves at designated intervals, a majority of your duties in connection with turbine plant operation are related to the lubrication system. One chapter of *Machinist's Mate 3*, NavPers 10522, deals with lubricants and the lubrication of machinery. A review of the information in that chapter and a thorough knowledge of the supplementary information in the following paragraphs will be helpful to you in preparing for advancement.

The need for cleanliness at all times in the operation of lubrication systems must be constantly kept in mind. Lubricating oil may lose its lubricating qualities if it is contaminated; if the impurities and water are removed as soon as their presence is noted, however, the oil can be used over and over again. To ensure that the oil is kept free of all foreign matter the entire lubrication system must be given careful attention at all times.

Each time a turbine installation is put into operation, you must make sure that all parts of the lubricating-oil system are in satisfactory operating condition and that the oil is free of impurities. To do this, proceed as follows:

1. Carefully note and record the readings of the oil level indicators.
2. Examine and clean all strainers.
3. Start an oil-service pump in each system, circulate the oil, and maintain a steady average service pressure at all bearings of the main engines and at all auxiliaries connected to the main system. If duplicate steam and electric lubricating oil-service pumps are installed, both should be tested; automatic controls, if fitted, should be used. Motor-driven pumps should be tested with alternate sources of electric power. Main lubricating-oil pumps should be operated on their pressure regulators, if fitted. Unless instructions indicate otherwise, the oil should be circulated through the lubricating system for at least one hour before the ship gets under way.
4. The temperature of oil supplied to the reduction gears must be at least 90° F. before the units are turned over. If the oil is below this temperature, it should be heated to 100° F. by use of the centrifugal purifier preheater, if provided; or by use of the auxiliary exhaust steam connection to the oil cooler, if such a connection is provided; or by heating in the settling tank.
5. Start the oil cooler circulating pump, if one is installed, to ensure that the circulating water system is in operating condition.
6. Inspect all bearings carefully. Ensure that there is an ample supply of oil at each bearing and that there are no leaks. Note oil flow to bearings by means of the sight glasses, if fitted. If trouble is experienced with either the oil supply or the tightness of the system, the trouble must be corrected immediately.
7. Inspect the oil-cooling system for leaks, and remedy any that are found.

8. Test the emergency cooling connections from the fire main; and the connections from the main circulating pumps, if fitted.
9. Test the low-pressure alarm by decreasing the oil pressure until the alarm sounds. If the alarm is found to be inoperative, remedy the defect at once.
10. Secure the cooling system until it is needed.
11. Maintain sufficient pressure on the oil-service lines to ensure that the pressure recommended in the manufacturer's technical manual will be maintained on all bearings.
12. Sample the oil, using the oil cooler or oil purifier test cock, to see whether any water has collected in the system.
13. When getting under way, regulate the oil pressure to meet the conditions under which the ship is operating.
14. To ensure against leakage of salt water into the oil through leaky coolers, never cut in the coolers until after the oil pumps have been started, and always secure the coolers before securing the oil pumps.

USE OF AIR EJECTORS (NOTE 3).—The gland exhauster and the second stage of the air ejector should be placed in operation just prior to, or simultaneously with, the admission of steam to the gland sealing system. The vacuum prescribed on the warming up checkoff sheet should be maintained. The first stage of the air ejector should be cut in just before the engineering department is reported ready for getting under way. (See *Machinist's Mate 3,* NavPers 10522.)

PRECAUTIONS (NOTE 4).—Auxiliary-exhaust steam must not be admitted to the main turbines during the warming up period. Warming up steam may be admitted only to the turbine steam-chest; steam must not be admitted at any point along the rotors.

The drains from the steam line, strainer, throttle, and

turbine must be opened to ensure that all water will be drained from these parts.

The lubrication system must be in operation before the rotors are turned over.

Warming Up the Turbines (NOTE 5)

In warming up a turbine it is well to remember that the rotor and the casing must be evenly heated; otherwise, unequal expansion will take place and will produce distortion of the rotor or the casing or both. The results of such distortion are not noticeable in small turbine installations; in large installations, however, the cumulative effect of distortions due to temperature change and unequal expansion is very noticeable, and, unless extreme care is taken, serious damage, such as rubbing of blades or packing, will result.

When you are standing watch in the engineroom you should be able to detect any unusual rubbing or grinding sounds and be able to locate the trouble quickly. At any time that an unusual noise is detected, the turbine should be stopped immediately in order to prevent damage to the installation. No unusual sound is so trivial that it can be neglected. An engineer's stethoscope or a listening rod will be helpful in detecting faint or indistinct sounds.

Two procedures are used in the warming up of a turbine: jacking the turbine; and spinning the turbine. The jacking procedure is used during a normal warming up; the spinning procedure is used when the ship is standing by to get under way and the jacking gear has been disconnected.

JACKING THE TURBINE (NOTE 6).—During warming up or cooling-off of the turbine, the rotor must not be permitted to remain at rest for any appreciable time while steam, (including gland steam) is being admitted to the turbine. The jacking gear, or turning gear, should be put into operation to roll the turbine rotor before steam is admitted to the turbine glands. After sealing steam has been admitted to the glands for at least 15 minutes, the

jacking gear may be disconnected and the turbine spun with steam.

SPINNING THE TURBINE (NOTE 7).—The procedure involving spinning the rotors must be used after the jacking gear has been disconnected. Where a jacking gear is not provided, the spinning is begun as soon as the gland steam has been admitted. When the turbine is ready to be rolled, open the throttle wide enough to admit sufficient steam to start the rotors turning at once, in order to avoid unequal heating of the rotor and consequent distortion. BE CAREFUL NOT TO PUT WAY ON THE SHIP. It is preferable to open the astern valve first, so that any condensate inadvertently left in the piping will be discharged through the large nozzles and the fewer rows of blading in the astern turbine, rather than through the many rows of the smaller blading of the ahead element. Puffs of steam, admitted to the turbine by opening and then immediately closing the throttle, start the rotor more quickly than does a slight, steady supply of steam. The puffs are also less likely to heat the rotor unevenly.

After the turbines have been spun astern, repeat the process immediately with the ahead throttle. Do not let the rotors stand still more than an instant with steam flowing into the turbines. For high-speed turbines driving double reduction gears (which is the type you will generally be operating), this procedure of alternately spinning the astern and ahead turbines should be repeated every 3 to 5 minutes, or at more frequent intervals if necessary.

STANDING BY PROCEDURES

After a turbine installation has been warmed up and is ready for operation, the procedure to be followed will depend upon the length of time that the ship is to remain in stand by condition.

Standing By Indefinitely

When a ship is standing by for an indefinite period of time, the condition of the propulsion plant will depend

upon how much time has been allowed the engineering department for changing from the stand by condition to the "ready to answer all bells" condition. The principal variations will be in the condition of the boilers and in the number of auxiliaries in use. If a ship is to stand by for several hours, the stops on the boilers which are not furnishing steam for auxiliaries should be closed.

Standing By for Getting Under Way

When a ship is standing by with orders to be ready for getting under way in thirty minutes, the following must be accomplished:

1. Open the recirculating valve between the deaerating feed tank and the condenser to the extent necessary to prevent overheating the feed tank and to ensure the removal of oxygen from the system.
2. Secure the first stage of the air ejector, and maintain vacuum with the second stage of the ejector.
3. Using one lubricating-oil pump in each engine room, maintain the required oil pressure at the bearings.
4. Maintain the lubricating oil at the required temperature.
5. Keep the gland steam at such pressure that the desired vacuum is maintained.
6. Crack the turbine and throttle drains.
7. Slow down the main circulating pumps so that they supply a flow of water just sufficient to maintain the required vacuum. If necessary, throttle the overboard discharge.
8. Open the warming up valve; keep the main steam line warm up to the throttles.
9. On ships equipped with motor-driven turning gears, use the turning gears to keep the turbine rotors turning continuously until word is received to get ready to get under way. On ships not equipped with motor-driven shaft-turning gears, turn the turbine rotors with steam every 5 minutes, alternately ahead and astern; care must be taken to prevent

fouling the propellers and to prevent putting way on the ship.

"Get Ready to Get Under Way" (Note 8)

The procedure outlined below is typical of those followed when orders are received (after standing by for a short time) to get ready to get under way:

1. Cut in the first-stage air ejector.
2. Close the recirculating line from the feed tank to the condenser.
3. Speed up the auxiliaries, and open wide the overboard discharge valves if they have been throttled down.
4. Close the turbine and throttle drains.
5. Disengage the shaft turning gear, if provided; and turn the turbines over with steam, being careful not to put way on the ship.
6. Close the warming up valves.
7. Report READY.

Precautions (NOTE 9)

When a turbine is being warmed up, and after it has been warmed up, a vacuum must not be maintained on the turbine unless the glands are properly sealed. Air leaking in along the shaft, particularly when the shaft is standing still, tends to cause distortion of the shaft and rotor. If the rotor becomes distorted under standing-by conditions, close the drains to the condenser and bring the pressure of the gland steam to between ½ and 2 psi above that of the atmosphere; then spin the rotor, alternately astern and ahead, after securing permission from the bridge.

If the oil supply fails at any time, stop the engines. Even momentary loss of flow of lubricating oil will result in localized overheating and probably in slight wiping of one or more bearings. Operation with wiped bearings will cause serious damage to shaft packings, oil seals, and blading. Stopping rotation of the shaft and restoring

lubricating-oil flow will prevent or minimize damage. (See chapter 10 of this training course for additional information on lubricating-oil system casualties.)

UNDER WAY OPERATIONS

In addition to being familiar with the procedure which must be followed after a ship is under way, you should be familiar with factors which are related to the steps that are taken. Also, you should have a thorough knowledge of the checks and inspections which must be made when a ship is under way.

Procedures After Getting Under Way

When the ship is under way and orders relative to standard speed have been received, the following steps should be taken:

1. Shift to the proper combinations for the set standard speed.
2. Open the proper number of nozzles to obtain maximum steam-chest pressure. (See NOTE 13).
3. Adjust the gland steam pressure to the required pressure. (See NOTE 10.)
4. Close the turbine drains.
5. Regulate the speed of all auxiliaries.
6. Examine all bearings; verify that oil is being supplied to each bearing.
7. Ensure that astern valves and bypasses are tightly closed.
8. If vacuum is low, search for leaks, look for open drains and valves, check to see that the overboard discharge is wide open, and open the valve on the condenser head to make sure the condenser is not air-locked. (See NOTE 10.)
9. Check the shaft revolutions.
10. Measure and record turbine clearances. (See NOTE 14.)

Notes On the Operation of Impulse Turbine Installations (General)

Under way procedures must be carried out in a manner that enables the ship to accomplish its mission with the greatest operating economy possible. Economical and efficient operation of a propulsion plant, under varying conditions and speeds, necessitates the maintenance of a high vacuum and the proper use of the cruising and maneuvering combinations.

IMPORTANCE OF HIGH VACUUM (NOTE 10).—In order to attain the greatest operating economy, the vacuum for which the turbine was designed must be maintained. Therefore, the necessity for the prevention and detection of air leaks in the vacuum system can not be overemphasized.

When the steam pressure within the turbine is greater than atmospheric pressure, steam tends to leak out of the turbine to the surrounding atmosphere. On the other hand, when the pressure in the turbine is less than that of the atmosphere, air tends to leak into the turbine and impair the vacuum. To prevent air leakage into the turbine and steam leakage from the turbine, steam is led to the glands and the pressure on the glands is maintained slightly greater than that of the atmosphere, generally ½ to 2 psi.

To ensure that the optimum vacuum will be maintained, care must be taken that the astern throttles do not leak; any leakage of steam past a closed throttle tends to raise the temperature and to increase the pressure within the turbine.

If the following precautions are observed, there will be little difficulty in maintaining the prescribed vacuum:

1. Gland packing must be kept in good condition.
2. A steam pressure between ½ and 2 psi gage must be maintained on the glands when the turbines are in operation.

3. There must be no air leaks in the condenser, exhaust trunks, throttles, lines to air ejectors, gage lines, idle condensate-pump packing and valves, make-up feed lines, etc.
4. Adequate water must be maintained in the feed tank on which the vacuum drag is being taken.

Cruising combinations (Note 11).—A combatant ship operates most of the time at speeds far below the maximum; at cruising speeds, therefore, there is required only a fraction of the power for which the main turbines are designed. Operating economy at these lower speeds is attained either by the use of cruising turbines, which are specially designed to operate at reduced speeds, or by the use of cruising stages in the high-pressure turbines; and by arranging the turbines so that they can be run in series. The cruising combination should be used whenever the standard speed is such that the combination can furnish the required number of revolutions.

Some impulse-turbine installations are equipped with cruising turbines; others are not. To effect economy in fuel consumption when a ship cruising at lower speeds with an installation which is not equipped with a cruising turbine, the high-pressure turbine is usually constructed with a cruising stage, or belt, which is bypassed during high-speed operation. In a few older installations, the auxiliary-exhaust piping is so arranged that auxiliary-exhaust steam can be directed into various stages of the turbines; in this way, the heat energy in the auxiliary exhaust is used to aid in driving the main engines.

Some impulse-turbine installations are equipped with cruising turbines. In such installations, the cruising turbine is permanently connected to the high-pressure turbine by means of a reduction gear. This arrangement eliminates all the clutch and synchronizing troubles which were common to older installations, in which the cruising turbine had to be unclutched for high speeds.

Protection of cruising turbines.—Protective devices

and precautionary measures are required if casualties to cruising turbines are to be prevented.

Protective devices include sentinel valves, retard-compound gages, direct-reading thermometers, cross-over valve locks, and thermal alarms. On some installations cooling steam is piped from the inlet of the high-pressure turbine to the steam chest of the cruising turbine. On other installations cooling steam is provided to the cruising turbine by "cracking" the cruising throttle during operation on the full-power combination.

On full-power combination, the exhaust from the cruising turbine to the high-pressure turbine must be closed tightly; otherwise, high-pressure steam will enter the cruising turbine. The connection from the cruising-turbine exhaust to the condenser must be opened wide to permit the condenser to evacuate the cruising turbine. If the valve in the line from the cruising exhaust to the condenser is not opened (or if chattering causes it to close), or if the exhaust from the cruising turbine to the high-pressure turbine is not tightly closed (to prevent a backflow from high-pressure to cruiser), pressure will build up in the cruising-turbine casing, the blades and parts of wheel rims will melt, and the molten metal will be deposited centrifugally around the turbine casing. Such a condition would necessitate a complete replacement of the cruising turbine.

When a ship is operating on maneuvering combination, the following precautionary measures should be taken at frequent intervals to prevent casualties to cruising turbines:

1. Be sure that the cross-over valve in the line from the cruising-turbine exhaust to the high-pressure turbine is tightly closed; if it is not, high-pressure steam will enter the cruising turbine.
2. Be sure that the cross-over valve in the line from the cruising-turbine exhaust to the condenser (installations where the valve is operated independ-

ently of the cross-over valve in the line from the cruising-turbine to the high-pressure turbine) is fully opened; the valve must be fully open to allow the condenser to evacuate the cruising turbine.

3. Check the cruising turbine retard-compound gage to be sure that the safe operating pressure is not exceeded.

TURBINE VIBRATION (NOTE 12).—If a turbine begins to vibrate as its speed is increased, the turbine should be slowed down immediately. If the vibration ceases at a lower speed, maintain that speed for several minutes; then attempt to build up the speed again. If no further vibration is noted, it may be assumed that the trouble was probably due to unequal heating of the rotor or to an accumulation of water in the turbine. If the vibration does not cease at a lower speed the turbine must not be used, except in an emergency; and steps must be taken immediately to locate and remedy the trouble. If, after the turbine has been running at a reduced speed for some time, the vibration again occurs at the higher speed, a speed limit lower than that at which vibration occurs must be set; and this reduced speed must not be exceeded until the trouble has been eliminated.

USE OF NOZZLES (NOTE 13).—In all modern turbine installations, the flow of steam to the cruising and high-pressure turbines is controlled by cam-operated or bar-lift valves. These valves are mechanically connected so as to open and close in the proper sequence. In some older installations, however, steam flow to the nozzles is controlled by the manual operation of individual control valves. (See Nozzle Control Valves, *Machinist's Mate 3*, NavPers 10522.)

It is essential that the pressure in the steam chest be kept as high as practicable. High pressure here allows for greater steam expansion and a resulting increase in the useful work obtained from the steam. The fewer the nozzles in use, the higher will be the chest pressure;

therefore, it is essential that installations which are fitted with individually operated nozzle valves be operated (at either low or high speeds) with the minimum number of nozzles required to obtain the desired speed. Adjacent nozzles should be used to ensure uniform stresses in the turbine blades, and the nozzle valves in use must be opened wide. The nozzle valves not in use must be tightly closed; otherwise, the resulting steam leakage will reduce turbine efficiency.

TURBINE-BLADE CLEARANCE (NOTE 14).—In an impulse turbine, the axial distance of the moving blades from the casing or the stationary blades is known as the axial blade clearance. This clearance may be determined by means of a finger piece, a rotor-position micrometer, or a clearance indicator.

A ready visual check on the fore-and-aft clearance of the turbine rotor may be obtained from the FINGER PIECE. In most cases, the finger piece consists of an indicator fastened to a plate which is secured to the turbine case. The indicator extends almost to the shaft. Usually three lines are scribed on the shaft to show the normal position and the maximum positions. In some cases, however, the indicator extends into a groove in the shaft; in these cases, the distance from the indicator to the shaft shoulder may be measured with feelers to determine fore-and-aft clearance.

The axial clearance of a turbine rotor may be determined with a ROTOR-POSITION MICROMETER. This instrument can be used when the rotor is either revolving or at rest. The micrometer is mounted at the forward end of the turbine shaft, with the spindle in line with the centerline of the shaft. When the micrometer is being used, the spindle contacts the end of the shaft at the center. The reading obtained is compared with established limits to determine if the position of the shaft is satisfactory. Care must be exercised to prevent the end of the micrometer spindle from becoming worn by long or hard contact with the rotating shaft.

In some installations, the axial blade clearance of a turbine rotor is determined with a CLEARANCE INDICATOR. The indicator may be used when the turbine is in operation. The instrument consists of a scale plate and an indicator, mounted within a bracket which is bolted to the turbine casing. The scale plate has scribed lines showing the normal position (midposition) and the maximum and minimum positions. One end of the indicator is made in the shape of a pointer, and a roller or contact surface is mounted on the other end. The indicator operates on a pivot. To take a reading, it is only necessary to press the arm of the indicator so that contact is made between the shaft and the roller, and then note the position of the pointer on the scale.

OPERATING WITH MANEUVERING COMBINATION (NOTE 15).—When a ship is getting under way, coming to anchor, or steaming in narrow or dangerous channels, high power for short intervals is often required. When operating under these conditions, therefore, a maneuvering combination is used. Such an engine combination is capable of delivering immediately the power required in response to any signal from the bridge.

When a ship is operating with a maneuvering combination, consideration must be given to a number of factors. Included in these are the condition of the valves and drains, the use of the pumps, and the manipulation of the steam throttles.

When an impulse-turbine installation is operating under maneuvering conditions, the CONDITION OF THE VALVES AND DRAINS should be as follows: the ahead and astern bypass valves must be closed; the stop valves and emergency valves in the line supplying steam to the throttle must be wide open; and the throttle and turbine drains must be kept open.

The importance of maintaining an adequate supply of cooling water to the condensers must not be overlooked under any condition of operation; it is essential, therefore, that you be familiar with the proper USE OF CIRCU-

LATING PUMPS when a ship is maneuvering. On ships equipped with scoop circulation, pumps are not needed while the ship has headway, provided the check valve is balanced by a counterweight on the lever; the pumps must be in operation, however, when slow, stop, or astern bells are either expected or being received. If an emergency-astern signal is received when a ship is running ahead, it is not necessary to start the circulating pumps before closing the ahead throttle. Keep in mind that the circulating water will scoop through the condensers as long as the ship has headway and that the ship will not lose headway until well after the propeller has begun to turn astern.

When the maneuvering combination is in use, the steam consumption is far greater than when a ship is operating under other conditions. It is important, therefore, that the steam be utilized as efficiently as possible, through the proper USE OF THE THROTTLE, when a maneuvering signal is received. The throttle should be opened so as to prevent the steam pressure from falling below a specified limit (about 85 percent of the safety-valve lifting pressure). The throttle must not be opened wide suddenly; to do so would result in rapid and excessive lowering of the main steam pressure. As steam pressure decreases, the auxiliaries slow down; if the line is bled to a great extent, there may not be sufficient steam left in the boilers for the ship to perform the maneuver. Sudden opening of the throttle may also cause priming, which not only causes a slowing down of the main machinery, but may result in serious damage to the installation.

Routine Under Way Inspections

Periodic inspections of the propulsion plant must be made if the plant is to be kept operating efficiently. When a ship is under way, the following items should be checked or inspected at very short intervals during each watch:

1. Bearings, to detect signs of overheating.
2. Sight glasses, to check flow of oil.
3. Finger piece or clearance indicator, to determine rotor position.
4. All gages, to check pressures and temperatures.
5. Oil supply sump tank, to determine if an adequate supply of oil is available.

PREPARATIONS FOR COMING TO ANCHOR AND SECURING MAIN ENGINES

From the time word is passed that the ship is expected to anchor until the main engines are secured and the auxiliary watch is set, Machinist's Mates have many jobs to perform. The auxiliary machinery to be used in port must be placed in operation, the deck machinery used in anchoring the ship must be warmed up, and numerous other tasks (varying with the type of ship) must be accomplished.

Procedure for Coming to Anchor

The procedure for coming to anchor includes:
1. Shifting to the maneuvering combination.
2. Warming up the necessary auxiliaries, and making preparations to answer all bells.
3. Shifting the auxiliary exhaust from the main condenser to the auxiliary condenser.
4. Opening the turbine drains as soon as a stop or an astern bell is received.

Procedure for Securing the Main Engines

The following steps are typical of those taken when the main engines of a geared turbine installation are being secured.

Action to be taken	*Time after receiving orders to secure*
1. Secure throttle valves................	Immediately.
2. Rotate turbine rotors with turning gear. (Lubricating oil pressure is to be maintained on all bearings)..........	Immediately after closing the throttle valves.

Action to be taken	Time after receiving orders to secure
3. Open throttle drains	Immediately.
4. Recirculate condensate and feed water.	Immediately.
5. Slow down auxiliary machinery and secure steam to first stage air ejector	Immediately.
6. Open turbine drains	Immediately.
7. Cut in auxiliary exhaust to the auxiliary condenser	As soon as practicable.
8. Start auxiliary feed pump and secure main feed pump	As soon as practicable.
9. Secure steam to second stage air ejector	As soon as practicable.
10. Secure gland steam and condensate pump	As soon as practicable.
11. Complete securing of air ejector, and break vacuum through air-ejector suction	When vacuum has dropped to 10 inches.
12. Secure main steam line; drain thoroughly before securing drains	As soon as steam can be controlled.
13. Secure main circulating pumps; close main injection and overboard discharge valves	Forty-five minutes.
14. Inspect to ensure that all root, throttle, and exhaust valves of all auxiliaries not in use are closed	When auxiliaries are secured.
15. Close all drains	When turbine is thoroughly cooled. (Within 24 hours.)
16. For all geared turbines, the lubrication system should be continued in operation for at least 1 hour after gland steam has been secured	Not less than 1 hour.
17. Drain water side of oil cooler to bilges.	When lubricating system is secured.

SUMMARY OF OPERATING PRECAUTIONS

The following precautions must be carefully observed when a steam propulsion plant is being started, operated, and secured.

Main Turbines

1. Do not use auxiliary-exhaust steam for warming up main turbines. (See NOTE 4.)
2. Be sure the lubrication system is operating before you turn main-turbine rotors. (See NOTES 2 and 4.)
3. Cut in gland-sealing steam as soon as the air ejectors have been started. (See NOTE 3.)
4. Keep the turning gear operating continuously while the main engines are being warmed up. (See NOTES 4 and 6.)
5. Investigate any unusual noise in the engines. (See NOTE 5.)
6. Do not put way on the ship when spinning the engines. (See NOTE 6.)
7. If a turbine vibrates, decrease the speed of the unit and determine the cause of the trouble. (See NOTE 12.)
8. Do not admit steam to an astern turbine until steam has been shut off from the ahead turbine, and vice versa.
9. Be sure, in getting under way, that all lines are properly drained. (See NOTE 1.)
10. When steam pressure drops, do not open the throttle to the extent that the pressure of the steam is brought to a dangerously low point. (See NOTE 15.)
11. Stop the engines if the oil supply fails. (See NOTE 9.)
12. If the throttle valve sticks open, close the bulkhead stop or guarding valve as soon as possible.
13. Break vacuum through the air-ejector vents—not by shutting off gland-sealing steam.
14. Maintain maximum vacuum and reduce superheat when running astern.
15. Keep throttle valves drained free of condensate at all times. (See NOTE 1.)
16. Determine rotor position at the beginning of main

turbine warm up and hourly during each watch. (See NOTE 14.)

17. Close the turbine drains about 24 hours after the throttle valves have been secured (if the turbine has thoroughly cooled).

Bearings

Because of the similarities in construction (*Machinist's Mate 3,* NavPers 10522) of the bearings in both the propulsion engines and the auxiliary machinery, the precautions listed here apply to the bearings of the engineering plant as a whole. If these precautions are observed, many operational casualties will be avoided.

1. Never use a piece of machinery if the bearings are known to be in poor condition.
2. Make certain that the bearings have the proper quality and quantity of lubricating oil before a machine is started.
3. Make certain that the operating temperature of each bearing is not above the specified normal for particular load and speed conditions. Investigate any abnormal temperature immediately. Rapid heating of a bearing is a danger sign. A bearing hot to the hand (at approximately 130° F. and over) after an hour's operation may be satisfactory, but the same temperature reached in 10 or 15 minutes indicates trouble.
4. If possible, give newly installed bearings a run-in period with no load.
5. Clean out the wells of self-lubricated sliding-surface bearings at frequent intervals, and see that the rings or chains run freely and do not drag.
6. When the salt-water circulating system is used, make sure that no oily water is pumped through stern tube bearings if they are lined with rubber strips.
7. Be sure that oil holes are open after a bearing has been rebabbitted.

QUIZ

1. Why must the main steam line be warmed up slowly?
2. If water hammer occurs when the main steam line is being warmed up, what has probably been overlooked?
3. How long should oil be circulated through the lubricating system of a steam propulsion plant before a ship gets under way?
4. When a steam propulsion plant is being prepared for operation, how may the oil be heated to the required temperature?
5. Why should the coolers in the lubricating system of a steam propulsion plant never be cut in until the oil pumps have been started?
6. In preparing a turbine installation for getting under way, when are the stages of the air ejector placed in operation?
7. What may result if the turbine rotor and casing are not evenly heated during warm up?
8. During turbine warm up, when should gland steam be cut in?
9. In spinning the turbine, should the ahead valve or the astern valve be opened first? Why?
10. Why are puffs of steam more desirable than a steady supply of steam for starting turbine rotors?
11. State briefly the procedure to be followed when a turbine rotor becomes distorted under standing-by conditions.
12. What should be done when the turbine lubricating-oil supply fails?
13. What should be done when vacuum is found to be low after a ship gets under way?
14. Why should a steam pressure between ½ and 2 psi gage be maintained on the glands when a turbine is in operation?
15. Why must the valve in the line from the cruising-turbine exhaust to the condenser be fully open when a ship is operating on full-power combination?
16. If turbine vibration ceases when speed is reduced and fails to recur when speed is increased, what will be the probable cause of the vibration?
17. Why should turbine installations fitted with individual nozzle valves be operated with the minimum number of nozzles required to obtain the desired speed?

18. In turbine installations fitted with individual control valves, why should adjacent nozzles be used?

19. What may be used to determine the fore-and-aft clearance of turbine blading?

20. What caution must be exercised when the rotor-position micrometer is being used? Why?

21. Should the throttle and turbine drains be open or closed when a ship is maneuvering?

22. When a ship is running ahead, is it necessary to start the circulating pumps before closing the ahead throttle?

23. Give two undesirable conditions which may be caused if the turbine throttle is opened wide suddenly.

24. Of the following steps, which must be taken when the main engines of a geared turbine installation are being secured, which must be performed immediately when the order to secure is received?
    (a) Drain water side of oil cooler to bilges.
    (b) Close all drains.
    (c) Secure steam to first stage air ejector.
    (d) Secure main circulating pumps.

25. When a geared turbine installation is being secured, the lubricating system must be kept in operation for at least how long after the gland steam is secured?

CHAPTER 3

TURBINES AND AIR EJECTORS

As an MM3, you should be familiar with the construction and operation of the principal types of main and auxiliary turbines used aboard naval installations. Information concerning these types of steam turbine propulsion plants and associated auxiliary machinery can be found in chapters 3 and 4 of *Machinist's Mate 3*, NavPers 10522. Additional information concerning the operation of the propulsion machinery installed in your ship can be found in chapter 41, section I, of BuShips *Manual;* and in the manufacturer's technical manual for the plant.

In this chapter we will discuss turbine performance, blading, accessories, propulsion turbine control and cruising arrangements, overspeed control, and the turbine maintenance factors which you must know in order to advance to MM2. Since you are also required to know how to clean air ejector steam strainers, a section on air ejectors is included in this chapter.

TURBINE PERFORMANCE

Every characteristic of a naval vessel is built into it to qualify the ship for a certain type of duty. Size, shape, compartmentation, machinery layout, speed, fuel storage capacity, etc., are all determined by the nature of the particular job which the ship will be required to perform. This is especially true of the propulsion plant used, and of the types and sizes of turbines installed in that plant.

The design of the turbines determines, to a large extent, the speed, power, and maneuverability of the ship—that is, the manner in which the steam generated by the ship's boilers is put to work. If the ship's designed effectiveness is to be obtained, the main turbines and their accessories must be carefully and efficiently operated and maintained, in accordance with the manufacturer's instructions.

The steam pressure at the throttle of a naval ship is between 350 psi gage and 1200 psi gage, approximately; and the temperature of this steam is between 650° F. and 900° F., approximately. Most turbine manufacturers believe that pressures and temperatures in excess of the maximum figures noted will require the use of special construction and materials which are not considered economically justified for marine or naval service.

It is important to note that the information contained in this chapter is of a general nature only. Turbine installations vary to such an extent that it will be necessary to refer to the manufacturer's technical manual for detailed information on a specific plant or unit.

IMPULSE AND REACTION TURBINES

The basic distinction made between turbines has to do with the manner in which the steam causes the turbine rotor to move. When the rotor is moved by a direct push, or "impulse", of the steam impinging upon the rotor

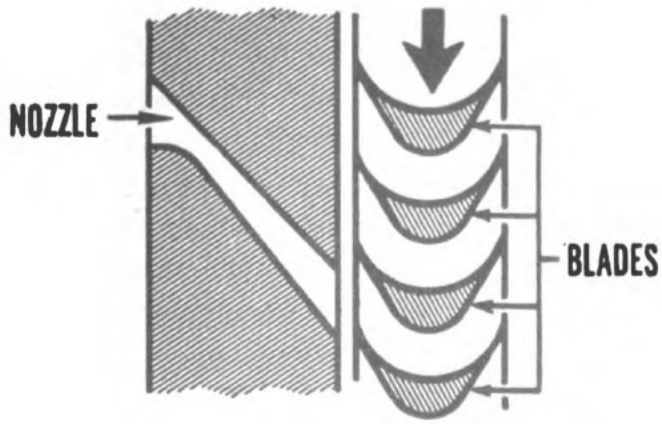


Figure 3–1.—Impulse turbine nozzle and blades.

blades, the turbine is said to be an IMPULSE TURBINE. When the rotor is moved by the force of reaction, the turbine is said to be a REACTION TURBINE.

The angle at which the steam hits the moving blades and the shape of the moving blades are the two main factors which determine whether the rotor is moved by a direct impulse or by reaction to an impulse. Figure 3–1 shows the nozzle and blade arrangement in an impulse turbine. Figure 3–2 shows the fixed blades and the moving blades in a reaction turbine.

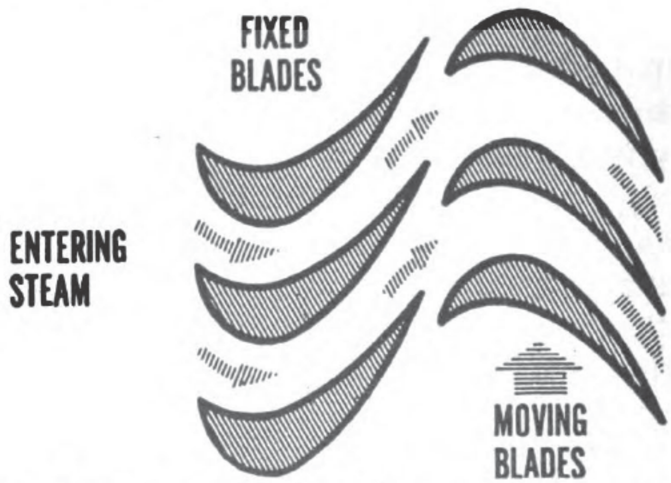


Figure 3–2.—Fixed and moving blades in a reaction turbine.

In the impulse turbine, as the steam expands in the nozzle it loses pressure and gains velocity. In the moving blades, the steam loses velocity but the pressure remains constant. Actually, an impulse turbine utilizes both the impulse of the steam jet and, to a lesser extent, the reactive force which results from the change of direction of the steam as it strikes the curved blades.

In the reaction turbine, the steam enters through a row of fixed blades which direct the flow of steam to the moving blades. Refer to figure 3–2 and notice that the fixed blades and the moving blades are very similar in shape. Steam expansion takes place in both sets of blades.

A reaction turbine is moved primarily by (1) the reactive force produced on the moving blades when the

steam increases in velocity, and (2) the reactive force produced on the moving blades when the steam changes direction. However, some of the motion of the rotor is actually caused by the impact of the steam on the blades; and, to a certain extent, therefore, the reaction turbine operates on the impulse principle as well as the reaction principle.

TURBINE BLADING

At this point, it is probably best to distinguish further between the terms impulse and reaction as they apply to turbine blading. Within any one stage of an impulse turbine.the only pressure drop is that which occurs in the nozzles. No matter what the number of fixed and moving blade rows in an impulse turbine, the pressure remains the same throughout the blading. However, the steam pressure decreases in each nozzle.

In the reaction turbine, the stationary blades perform the same function as the nozzles of the impulse turbine. The curved passages in the moving blades not only absorb some of the energy of the steam delivered to them by the ring of fixed blading, but they also generate energy by allowing an expansion within the passages; some of this energy is absorbed by the moving blades, and the steam finally leaves the moving blades with approximately the same velocity as that with which it entered the fixed blades, but with less pressure.

Impulse Turbine Blading

Blades for impulse turbines are made from corrosion-resistant steel (CRS) or from Monel metal. As a rule, the blades are made by machining solid bar stock; however, some blades are made by forging. All blades are machined to a smooth finish, in order to reduce friction to a minimum. Although there are many variations in the design of blades, most impulse blades are symmetrical and are shaped in the form of a semicircle.

Blade roots are dovetailed or serrated to match the

shape of the groove around the periphery or the rotor. The blades are inserted in this groove and are held in place by calking pieces, tapered wedges, or similar locking devices.

The outer circumference of each row of impulse blading is fitted with a band or cover, which is fastened to a projection at the tip of each blade. This band is called SHROUDING. The shrouding is installed to stiffen the blades and thus reduce vibration. In addition, shrouding serves to keep steam from flowing over the ends of the blades. When the blades are relatively short, shrouding is sometimes made integral with each blade, instead of being fastened over the blades. In this case, the integral shrouding of a blade fits very close to the back of the next blade.

Reaction Turbine Blading

All modern reaction blades are made of corrosion-resistant steel or of Monel metal. However, in some older installations which use relatively low steam pressure blades are made of (1) manganese-copper (600° F. and below), (2) cupro-nickel (600° F. and below), and (3) 70 percent copper, and 30 percent zinc (425° F. and below).

Unlike the shape of most impulse blades, the shape of reaction blades is not subject to geometrical construction. In order that steam may expand the correct amount without turbulence in the passages between adjacent blades, the passages must be in the form of correctly shaped nozzles. The cross-sectional size of the blades, their length, and the distance between blades are determined by the pressure of the steam in the various stages.

Securing Turbine Blades to the Casing and Rotors

Blades are secured to the turbine casings and rotors by various methods. Figure 3–3 illustrates the methods which are described briefly in the paragraphs that follow.

1. The STRAIGHT CIRCUMFERENTIAL DOVETAIL method, shown in figure 3–3A, is used primarily for securing rotor blades. Here a dovetail is machined in the rotor (or

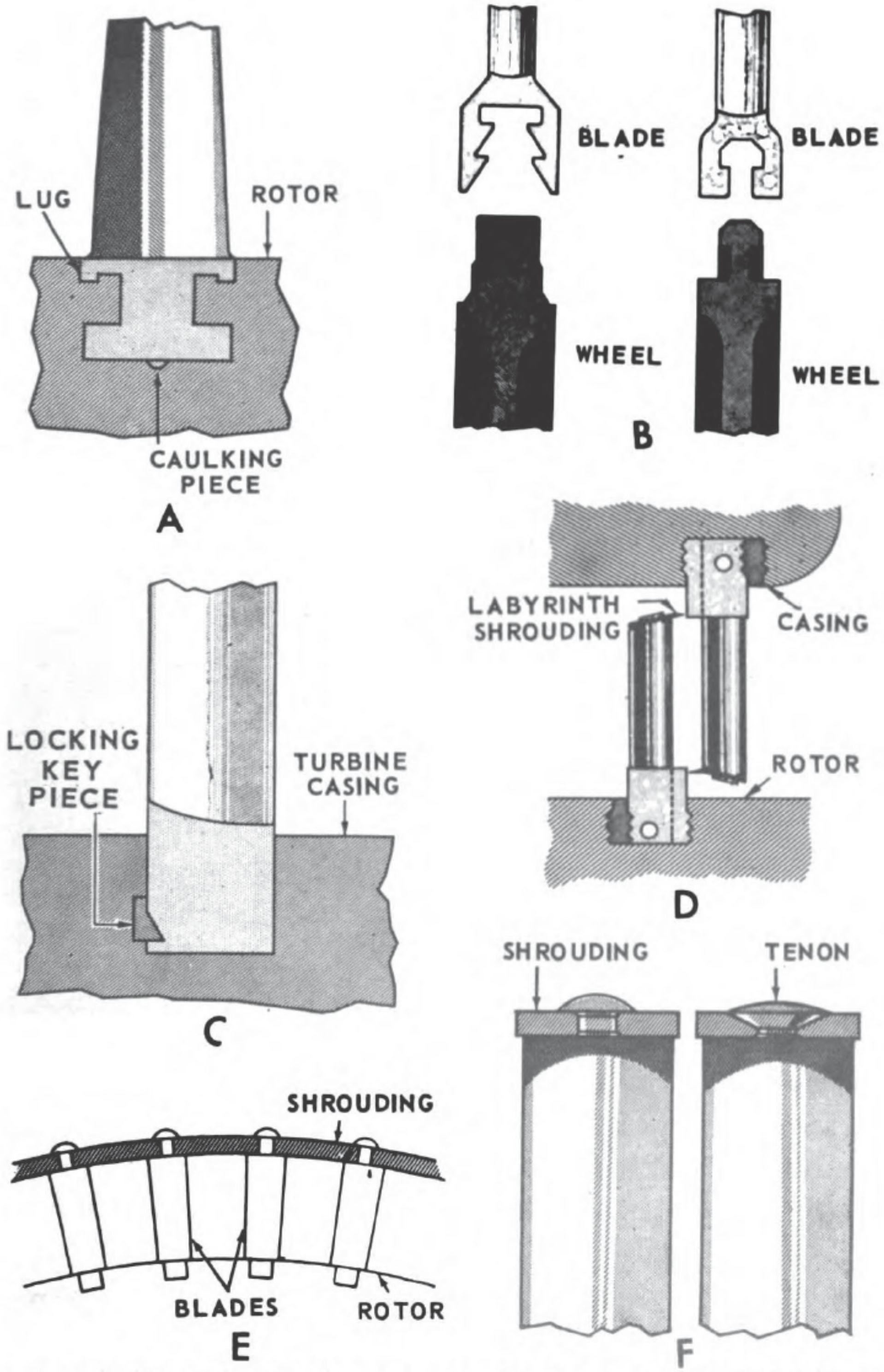


Figure 3–3.—(A) Turbine blade secured by the straight circumferential dovetail method; (B) inverted circumferential dovetail methods of securing turbine blades (single and double shoulder types); (C) turbine blades secured by the side locking keypiece method; (D) turbine blades secured by the saw-toothed serration method; (E) turbine blade shrouding; and (F) methods of securing shrouding to blades.

casing) into which are fitted the dovetailed roots of the blades. The side of the rotor dovetail is cut away enough so that one blade can be inserted. Each blade is driven up hard against the preceding one. A CALKING PIECE, driven into a shallow groove under each blade root, forces the blade root firmly up against the shoulders of the dovetail and holds it in place. A special locking piece (not shown in fig. 3–3), which just fills the space between the first and last blades, is inserted in the rotor, closing the cutaway section of the dovetail. This locking piece is keyed and calked or welded to hold it securely in place.

2. The INVERTED CIRCUMFERENTIAL DOVETAIL methods, shown in figure 3–3B, differ from the method described in the preceding paragraph in that the dovetail is machined into the root of the blade rather than into the rotor. In this method, the root of the blade is milled to a dovetail and is fitted over a circumferential projection machined on the turbine wheel. The space between the first and last blades of each row is fitted with a notch block, which is pinned securely into place. The double shoulder or pine-tree type of dovetail is employed for securing longer blades. The inverted circumferential dovetail method is used chiefly for impulse blading.

3. The SIDE LOCKING KEY-PIECE method, shown in figure 3–3C, consists of driving a locking key piece between the blade root and the side of the groove in the casing. Both the blade and the casing groove have notches in them so that when the key piece is driven in, it locks the blade root firmly in place. This method is used only on casing blades, which are not subject to the high stresses and centrifugal force of the rotating blades.

4. The SAW-TOOTHED SERRATION method, shown in figure 3–3D, is used for both rotor and casing blades. In this method, saw-toothed serrations are machined on the sides of the blade roots to mate with similar serrations machined in the rotor or casing groove. When the root is made undersized in width, as illustrated, SIDE LOCKING

PIECES are inserted and calked in to fill the serrations and lock the blades in place.

A thin metal strip or SHROUDING, shown in figure 3–3E, is attached to the ends of the blades by small protrusions, called TENONS, illustrated in figure 3–3F. Sections of the shrouding are drilled and fitted over the tenons, which are then peened over to hold the shrouding in place. This shrouding fits over the tips of the blades and the blade assembly. In addition to reducing steam leakage, the shrouding also helps to strengthen the blade assembly and to reduce vibration.

RE-ENTRY AND DOUBLE RE-ENTRY TURBINES

As an MM3 you learned that turbines may be classified with respect to the sequence of flow of the steam through the several elements which comprise the complete turbine (single-flow, compound-flow, double-flow, and triple-flow turbines). As you know, turbines may also be classified according to the direction of the flow of steam relative to the turbine wheel (axial flow, radial flow, and tangential, or helical, flow). Detailed information about these classifications of turbines can be obtained from chapter 3 of *Machinist's Mate 3,* NavPers 10522.

Turbines are also classified as single entry or re-entry, according to the REPETITION OF STEAM FLOW. If the steam passes through the blades only once, the turbine is called SINGLE ENTRY. All multistage turbines are single entry.

RE-ENTRY turbines are those in which the steam passes through the blades more than once. The helical-flow turbine shown in figure 3–4 is a re-entry turbine. Another type of re-entry turbine is shown in figure 3–5. This turbine is similar in principle to the helical-flow turbine; however, this re-entry turbine has one large reversing chamber instead of a number of smaller buckets or redirecting chambers.

The rotor of the re-entry turbine consists of a wheel with a single row of impulse blades. Steam enters the nozzle from the steam chest and acquires high velocity

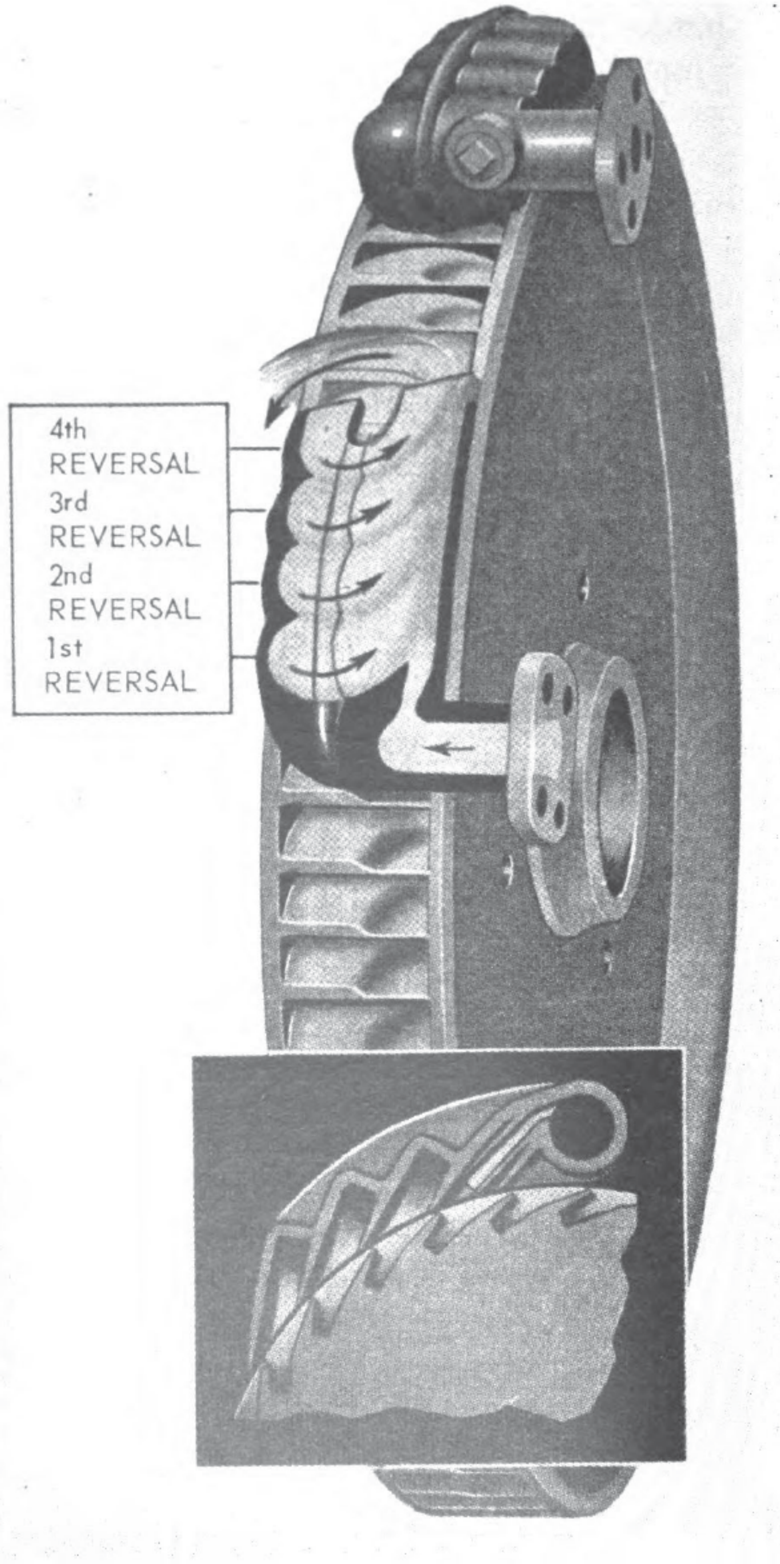


Figure 3–4.—Helical-flow turbine.

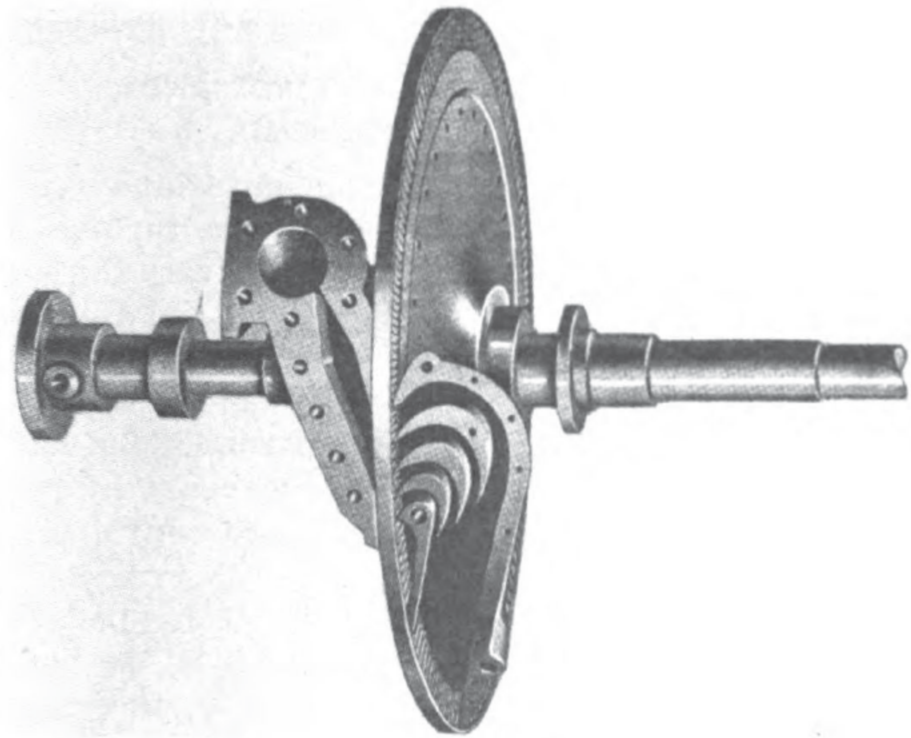


Figure 3–5.—Re-entry type turbine, with one reversing chamber.

and, hence, increased kinetic energy; it is then directed against the row of moving blades. After passing through the blades, the steam discharges into the reversing chamber. In this space, the direction of flow of the steam is reversed and the steam is directed into the row of moving blades again, but on the side opposite from the nozzle. The steam flows back through the blades, and exhausts on the nozzle side of the wheel. (This arrangement corresponds to a velocity-compounded stage with two rows of moving blades, in which the stationary blades are replaced by the reversing chamber.)

In some turbines a second reversing chamber is used (DOUBLE RE-ENTRY), causing the steam to flow through the moving blades three times. Since there is large frictional loss in the reversing chambers, the use of more than two chambers is unusual. The additional energy which would

be extracted by another passage of the steam through the blades would be offset by the increased friction losses.

PROPULSION TURBINE CONTROL AND CRUISING ARRANGEMENTS

The power developed by a propulsion turbine depends upon the amount of steam admitted to the turbine. The control mechanisms of propulsion turbines vary the speed, or power, as desired. Some of the methods and apparatus for effecting this control are described in the paragraphs which follow.

On the older types of propulsion installations, steam flow through the turbine is controlled manually by means of (1) a simple throttle valve, (2) nozzle control valves, and (3) bypass valves.

The THROTTLE VALVE, installed at the steam inlet of the turbine, is the primary means of controlling the flow of steam to the turbine. In some installations the throttle valve casting is bolted directly to the turbine steam chest, while in others it is at some distance from, and connected by a length of pipe to, the steam chest. By varying the amount of opening of the throttle valve, the pressure in the steam chest is raised or lowered, and the amount of steam admitted to the turbine is increased or decreased. The use of the throttle valve alone to control the flow of steam over the full range of turbine speed would result in a considerable loss in efficiency, particularly at the lower speeds (small throttle opening), caused by throttling loss. In addition, it is important to note that the maintenance of high chest pressures results in the most efficient pressure for the nozzles. For these reasons, propulsion turbines are fitted with NOZZLE CONTROL VALVES.

The high pressure ends of high-pressure turbines are fitted with impulse blading, which is usually of the velocity-compounded type. Steam is directed against this blading by nozzles which are usually fitted around the entire circle of blading. Steam is supplied to groups of these nozzles by nozzle chests. Each chest is fitted with a

nozzle control valve. Steam is admitted to the turbine first through the throttle valve to the steam chest, and then through the nozzle control valves to the nozzle chests and the nozzles. The arrangement of the throttle valve and nozzle control valves is shown in figure 3–6.

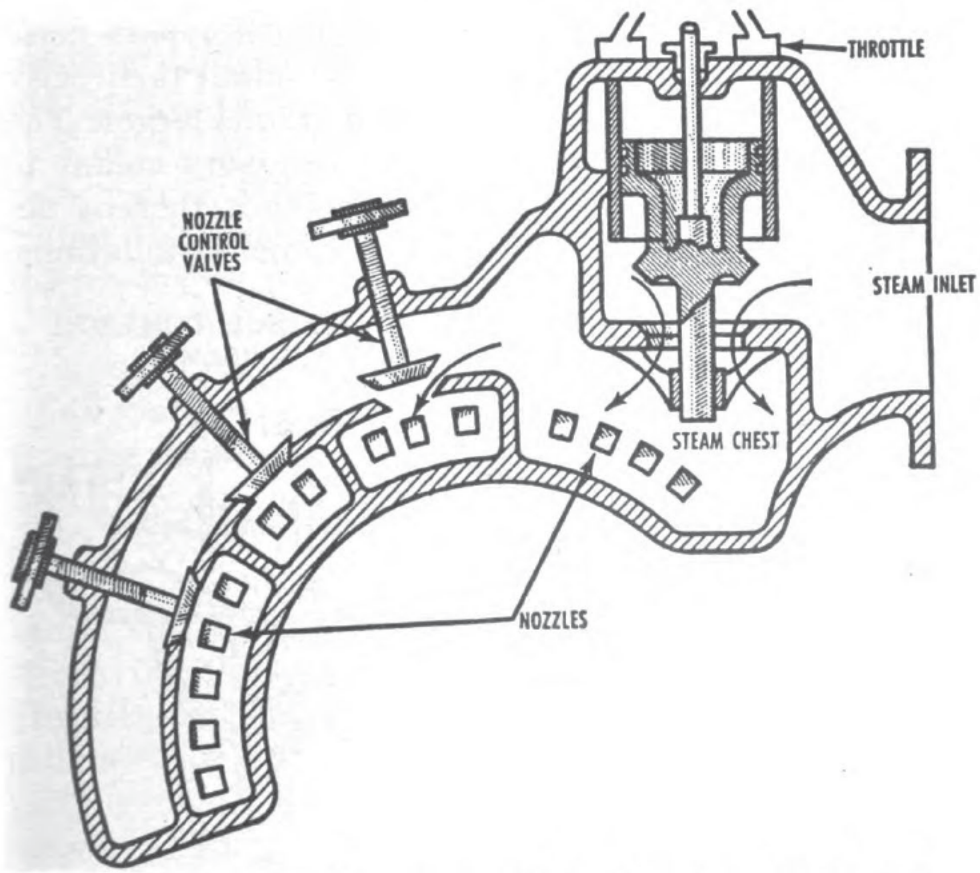


Figure 3–6.—Diagrammatic arrangement of throttle and nozzle control valves.

Since nozzles can be designed to operate at maximum efficiency only at specific inlet and discharge pressures, any variation from the designed inlet pressure will result in a loss of efficiency. Each nozzle chest supplies steam to a different number of nozzles; for any given speed, therefore, it is possible to maintain nearly full designed steam pressure on the nozzles in use by opening the proper combination of nozzle control valves. In addition, the throttling loss is reduced to a minimum because there is practically no pressure drop in the throttle. Minor variations

in speed within the capacity of any one nozzle control valve combination are taken care of by the throttle.

With the throttle and all nozzle control valves wide open, a point is reached where no more steam can pass through the turbine; the steam flow is limited by the cross-sectional area of the first stage nozzles. In order to further increase the flow, valves are installed which bypass most of the steam around the first stage, and admit it directly to a later stage where the total nozzle area is larger. The bypassing of a stage permits higher-pressure steam to work on the larger blades of the later stages, thereby developing more power. (On some turbine installations,

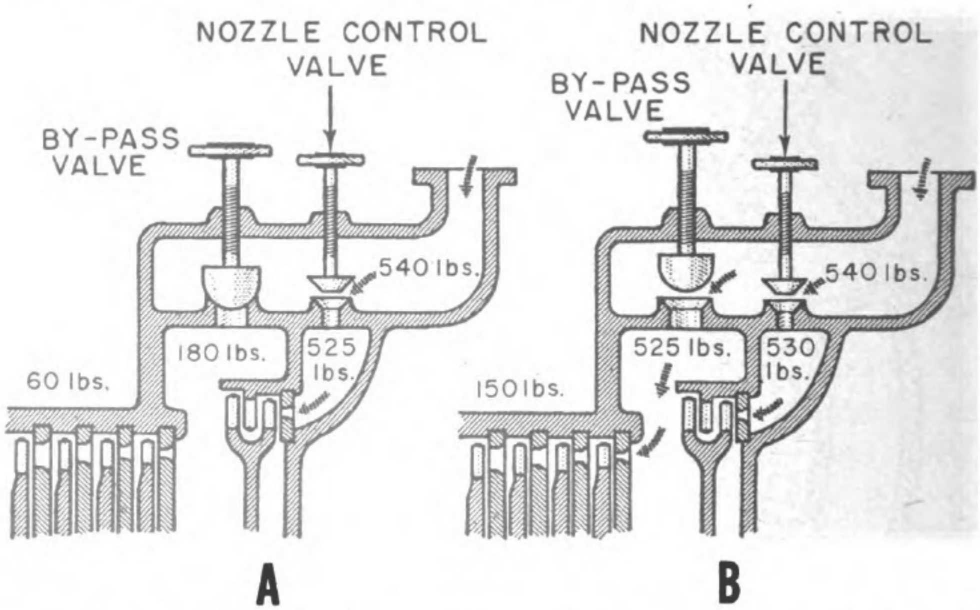


Figure 3–7.—(a) Diagrammatic arrangement of a bypass valve with the valve closed, and (b) diagrammatic arrangement of a bypass valve with the valve open.

several bypass valves are installed.) When a stage is bypassed, provision must be made to ensure a small flow of steam through the bypassed stage in order to keep it from overheating; therefore, the bypass valves are designed so that there is a small pressure drop across the corresponding stage. Figure 3–7 (a) and (b) illustrate diagrammatically the arrangement of a bypass valve and the steam flow, with the valve in closed and open positions.

Note that in figure 3–7 (b) the steam pressure in the second stage is slightly less than that of the first stage steam chest; this results in a small flow of steam through the first stage to prevent overheating.

Modern Propulsion Turbine Control

In order to simplify the operational aspects of control, some of the latest propulsion turbine control mechanisms are designed to combine, in a single handwheel, the operation of the throttle, the nozzle control valves, and the bypass valves. Since space limitations do not permit a detailed discussion of controls on all ship types, the following description of a battleship installation is given as a typical turbine control system. While details of the equipment vary with the class of ship, the basic principles of all systems are the same. The manufacturer's technical manual may be consulted for a detailed description of the turbine control system installed in any ship.

The control system shown in figure 3–8 consists of seven cam-operated valves for ahead operation and a single valve for astern operation, on each propulsion unit. Since the astern valve is nothing more than a simple throttle which admits steam to the astern turbine, no further description of it will be given. The opening and closing of all seven ahead valves is accomplished by a single cam shaft. Seven cams are so arranged on the shaft that they open and close the valves in proper sequence. The cam shaft is geared to a handwheel so that approximately 30 turns of the handwheel are required to open or close all valves.

Figure 3–8 shows the seven valves mounted on the top of the turbine; they are numbered in the order of opening. Valves No. 1, No. 2, No. 3, and No. 4 are nozzle control valves which open to admit steam to the first-stage nozzles. Valve No. 5 opens next to admit steam, through the first bypass, direct to the second-stage nozzles. Valve No. 6 opens next to admit steam, through the second bypass, direct to the fifth-stage nozzles. Then valve No. 7 opens

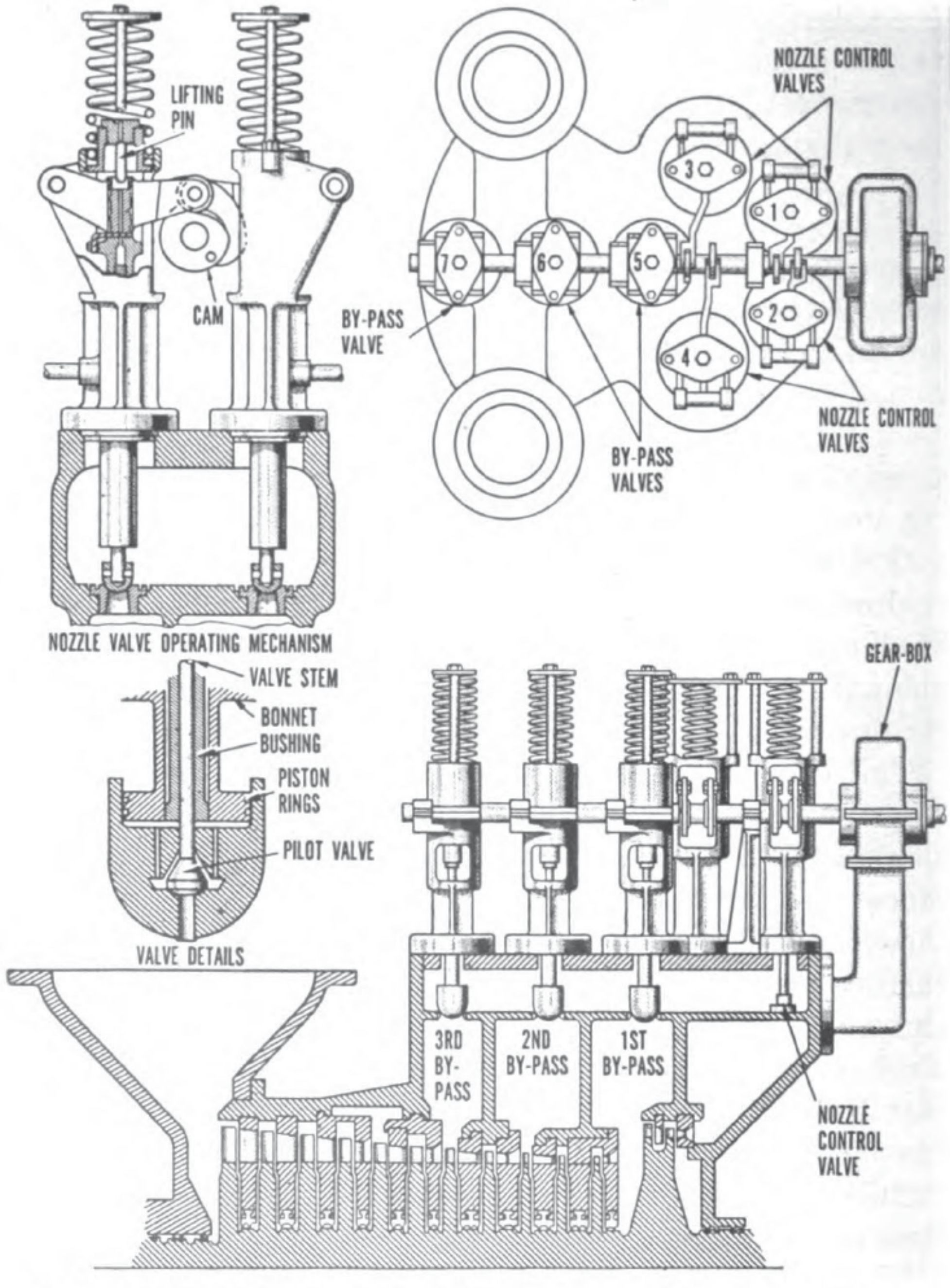


Figure 3–8.—Simplified sketch of a modern turbine speed control mechanism.

and steam is admitted, through the third bypass, direct to the seventh-stage nozzles. The force of the springs at the top of the valves returns the valves to their seats. There is no provision for changing the sequence in which the valves open.

An indicator, mounted on the handwheel, shows which valves are open. As soon as the indicator moves away from the SHUT position, valve No. 1 begins to open. The other valves open as the handwheel is turned counterclockwise. When the indicator reaches the OPEN position, all the valves are fully open. Turning the handwheel in the clockwise direction closes the valves in the reverse of the order in which they were opened.

Cruising Arrangements

For every ship there is a speed at which the fuel consumption per mile is at a minimum. This most economical speed is based upon the combined fuel consumption per mile of the propulsion engines and the auxiliary machinery. The fuel used by the engines in driving the ship through the water is approximately proportional to the cube of the speed of the ship. However, a considerable quantity of fuel is required by the auxiliary machinery, even when the ship is stopped; as the speed is increased, there is only a very gradual increase in the amount of fuel consumed (per hour) by the auxiliary machinery. Therefore, as the ship's speed is increased, the fuel consumed (per mile) by the auxiliary machinery actually decreases. These varying rates of fuel consumption for the auxiliary machinery result in a most economical speed, for turbine-driven ships, of between 12 and 20 knots, depending upon the type of ship.

In order to conserve fuel and thereby increase the ship's cruising radius, a major part of all steaming is done at close to the most economical speed; therefore, the most economical speed is generally designated as cruising speed. Although it is desirable to have the most economical speed as high as possible, there is a practical limit above which this speed cannot be raised (because of the progressively increasing resistance of water to the ship's hull as the speed of the ship is increased). Increasing the efficiency of the main engines will tend to raise the most economical speed.

It is also desirable for combatant ships to be able to steam at or near full power for long periods of time. This requirement makes it necessary for propulsion plants to be designed with a relatively high turbine efficiency at high speeds.

Maximum efficiency in a turbine is obtained when the optimum ratio of blade speed to steam speed exists. Therefore, in order to obtain the lowest possible fuel consumption per mile at cruising speed and at full power, it is necessary that propulsion turbines be designed so that the optimum ratio of blade speed to steam speed will be approached at both these speeds. This is accomplished by the use of (1) cruising stages and (2) cruising turbines.

CRUISING STAGES.—In order to attain the optimum ratio of blade speed to steam speed at or near cruising speed, high-pressure turbines are designed so that in the first few stages there are relatively small blades which have a large pitch diameter. These stages, usually velocity-compounded, are known as cruising stages. Cruising stages may be defined as those stages, incorporated into the high-pressure end of a high-pressure turbine, which provide for the optimum ratio, at or near cruising speed, of blade speed to steam speed.

The small blades in the cruising stages restrict the quantity of steam which can be passed, with a given steam-line pressure, through the turbine. Thus, while they increase the turbine efficiency at or near cruising speed, the small blades limit the steam flow and, therefore, the power which the turbine can develop. In order to permit a larger amount of steam to pass through the turbine, bypasses (fig. 3–7) are installed. (These bypass valves allow the steam to be bypassed around the cruising stages when high power is desired. The bypasses allow high-pressure steam to work directly on the larger blades of the later stages, thereby developing more power.)

CRUISING TURBINES.—In some installations, the optimum ratio of blade speed to steam speed at cruising speeds is attained by means of a separate, small turbine,

known as a cruising turbine. These turbines are similar in design to high-pressure turbines, except that they are smaller in size and are not fitted with bypasses. When a cruising turbine is in use, steam passes through the cruis-

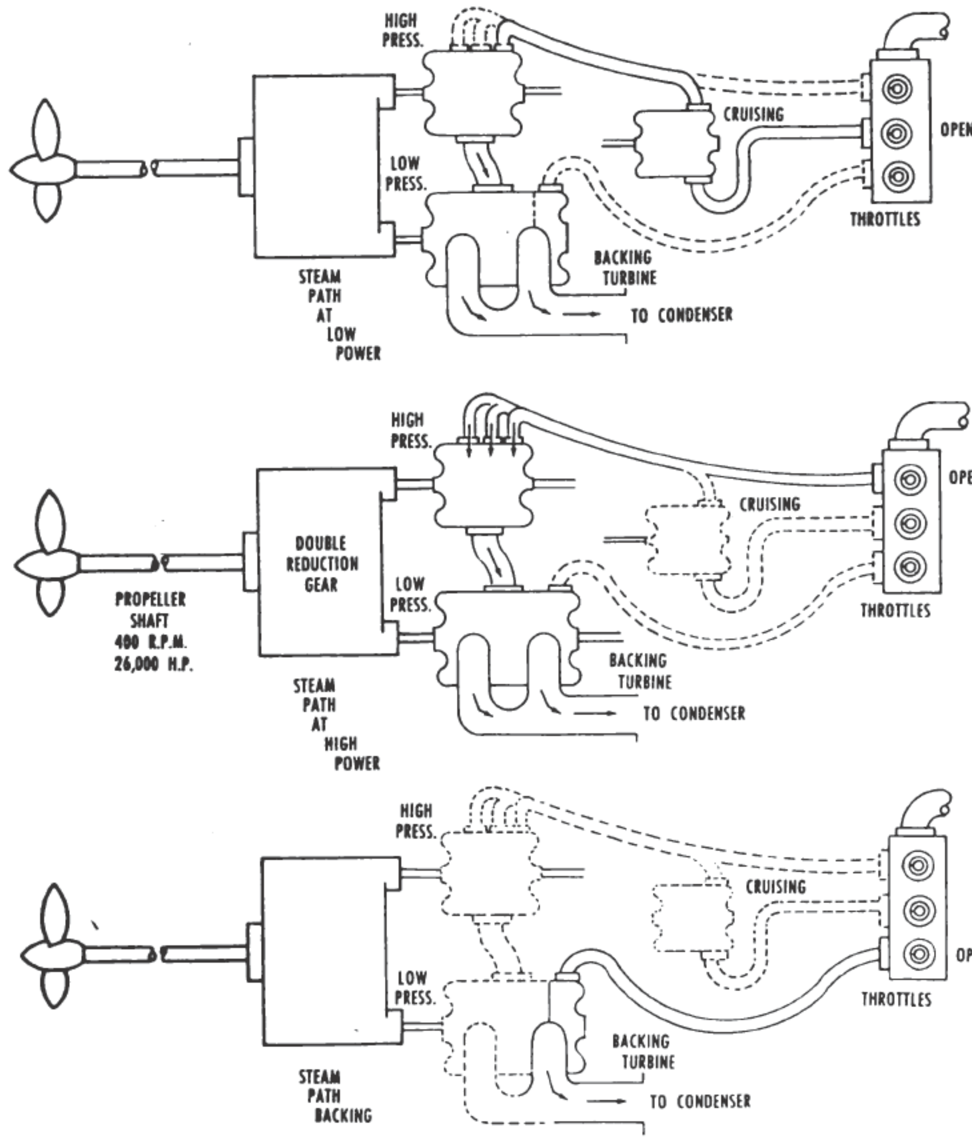


Figure 3–9.—Schematic diagrams of compound turbine cruising arrangements when a cruising turbine unit is included.

ing turbine before it goes to the high-pressure turbine (fig. 3–9). In this way, the steam is expanded through a greater number of pressure stages and more energy is extracted from the steam than would be possible by the

use of the high-pressure and low-pressure turbines. When speeds in excess of the cruising turbine's range are desired or anticipated, the steam is led directly to the high-pressure turbine, bypassing the cruising turbine. When cruising turbines are bypassed, cooling steam is supplied to the cruising turbine by means of a cross-over valve, installed on the cruising turbine exhaust, between the cruising turbine and the high-pressure turbine. Because of their high speed of rotation, cruising turbines are usually connected to the high-pressure turbine shaft through a reduction gear.

TURBINE OVERSPEED CONTROL

To prevent a turbine from overspeeding when its load is lost as a result of breakage of shafting, loss of the propeller, or excessive pitching and rolling of the ship which brings the propeller clear of water, various overspeed control mechanisms are used. Some of these mechanisms built are an integral part of the ahead throttle valve and others use a separate overspeed control valve. Most types of such mechanisms are hydraulically operated. Detailed information concerning a specific overspeed control mechanism can be obtained from the manufacturer's technical manuals.

One type of main turbine overspeed control mechanism, using a separate overspeed control valve, is illustrated in figure 3–10. Directly connected to each turbine shaft is a small centrifugal oil pump which takes suction from the turbine oil lines. The pressure developed by this pump is proportional to the speed of the turbine. The discharge pressure acts upon the piston in the emergency governor, and is opposed by the pressure of the governor spring. Excessive oil pressure developed by the governor oil pump causes the pilot valve of the operating cylinder to move to such a position that it shuts off the oil pressure from the service pump and allows the oil in the operating cylinder to drain. Then the spring in the operating cylinder pushes the valve stem up, and the overspeed control valve closes.

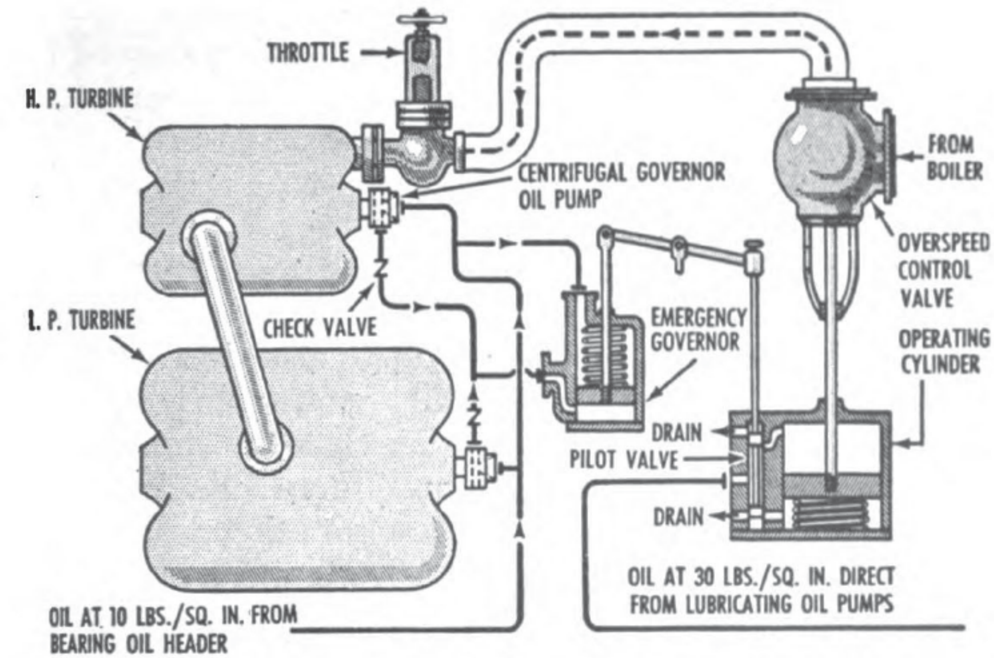


Figure 3–10.—Diagrammatic sketch of a main turbine overspeed control mechanism.

Tripping of naval propulsion turbines by low oil pressure or by overspeeding devices is no longer provided, except for electric propulsion generator turbines, or turbines arranged for unclutching (cruising turbines). Such control mechanisms were fitted on many turbine installations when the Navy started to use double-reduction gears and high-speed turbines. At that time, this was necessary because of the low moment of inertia of turbine rotors.

However, it has recently been discovered that all modern cruising turbines will not dangerously overspeed, even with sudden removal of the load. This is due to the small nozzle area which restricts the flow of steam, and to the windage which develops at high rotational speeds. While the nozzle areas of all low-pressure turbines are great enough to pass sufficient steam to overspeed the turbines, the moment of inertia of these large rotors is high, and, therefore, the rate of acceleration is low. Thus, in the event of overspeeding, the throttleman has more time in which to take action. For the above reasons, and also be-

cause such protective devices constitute a hazard during enemy action, low oil pressure trips and overspeed devices have been removed from most naval combatant ships.

AUXILIARY TURBINES

In addition to the large propulsion turbines, there are aboard ship a considerable number of small turbines which are used for driving auxiliary machinery such as generators, forced draft blowers, pumps, and air compressors.

In modern naval vessels, all machinery outside the engineering spaces, and many units within these spaces, are driven by electric motors. However, there are many auxiliaries located in the engineering spaces that are turbine-driven. These auxiliaries include main condensate pumps, main feed pumps, main feed booster pumps, main lubricating oil pumps, and main ship's service generators. The general practice is to duplicate some turbine-driven pumps with smaller motor-driven cruising and auxiliary pumps which are used at cruising speeds and in port. These motor-driven pumps have a comparatively high efficiency, but their capacity is not great enough to meet the demands of the plant at high speeds.

Aside from the fact that the turbine-driven units (particularly pumps) have a higher capacity than the motor-driven units, there are two additional important reasons for using turbines to drive auxiliary machinery:

1. Turbines ensure greater reliability than motor-driven units. The probability of interruption or loss of electric power supply is greater than the probability of loss of steam supply—especially during action.
2. Turbines improve the over-all efficiency of the plant by utilizing the exhaust steam from these turbines in feed-water heaters, evaporators, gland sealing systems of the main turbines, and where low-pressure steam is required. (Without this supply

of exhaust steam, it would be necessary to "bleed" steam from the auxiliary steam line through reducing valves, which is a very uneconomical process.)

In order to conserve space, auxiliary turbines are designed to have comparatively few stages (sometimes only one). This results in a large pressure drop in each stage, and a high steam velocity. In order to obtain maximum efficiency, the blade speed must also be high. Since several auxiliaries are necessarily moderate-speed machines, reduction gears are used to reconcile the two conflicting speed requirements, and increase the general efficiency of auxiliary turbines.

Classification of Auxiliary Turbines

Auxiliary turbines used by the Navy may be classified in accordance with characteristics such as speed, exhaust conditions, shaft position, type, steam-flow direction, number of stages, drive, service, and power output. Detailed information concerning auxiliary and main turbine characteristics may be obtained from chapter 3 of *Machinist's Mate 3,* NavPers 10522. For detailed descriptions and instructions for these turbines, refer to the respective manufacturers' technical manuals, and to chapters 41 and 50 of BuShips *Manual.*

Except for electric-generator turbines, auxiliary turbines are usually impulse turbines of either the helical-flow or axial-flow single stage type. They operate against a back pressure of 15 or 20 psi gage, depending upon the auxiliary-exhaust line pressure of the ship. (On the later destroyers, cruisers, aircraft carriers, and battleships, auxiliary turbines operate against a back pressure of 15 psi gage.) Turbines which drive electric generators are ordinarily of the impulse, axial-flow, multistage, geared type, and operate condensing.

Ship's Service Turbogenerators

Figure 3–11 shows a typical ship's service generator turbine capable of driving a 600-kilowatt a-c generator.

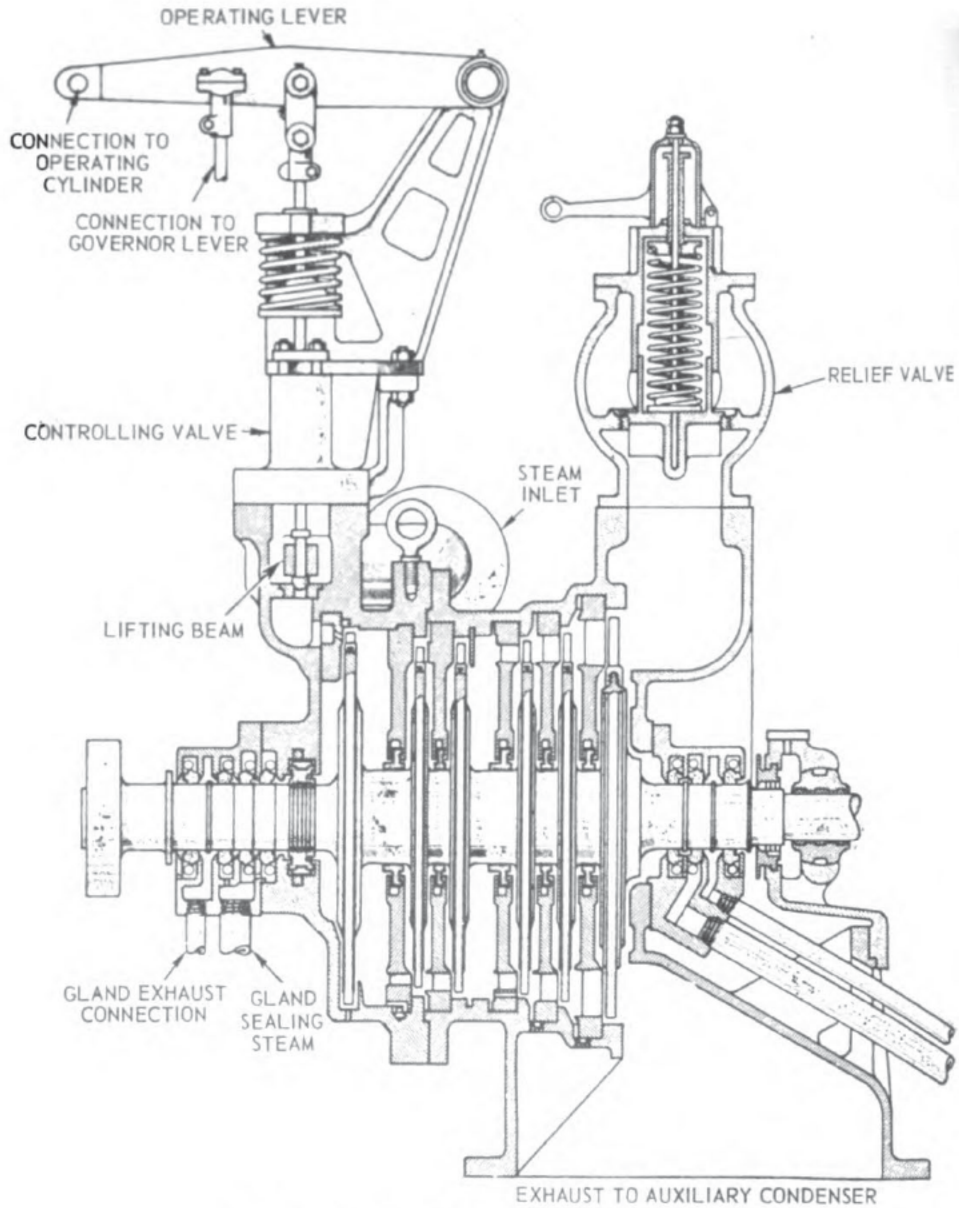


Figure 3–11.—Ship's service generator turbine.

The turbine is of the axial-flow, pressure-compounded, impulse type. The turbine exhausts to a separate auxiliary condenser which has its own circulating and condensate pumps and air ejector. Cooling water for the condenser is provided through separate injection and overboard valves, by the auxiliary circulating pump.

On some ships, in case of a condenser casualty, the turbine exhaust may be discharged directly to the atmos-

phere, or into the main condenser (when the main plant is in operation). A relief valve, installed on the turbine exhaust casing, relieves excess pressures which would build up within the turbine casing if the exhaust should be inadvertently closed while the turbine is in operation.

The ship's service generator turbine is designed to operate on either saturated or superheated steam at a pressure of 525 psi and at a maximum temperature of 825° F. at the throttle. Provision is made for supplying steam to the turbine either from the main steam line (superheated) while under way, or from a special turbo-generator line (saturated) during in-port operation, led directly from the boiler. The steam is admitted to the turbine through a throttle and nozzle control valves, under the control of a governor.

Turbine Governor System

Ship's service generators supply electricity for light and power throughout the ship. Since a constant voltage and frequency must be maintained on the ship's service lines, the generator turbine operates at a constant speed. This speed is maintained at a predetermined rate—regardless of load and exhaust-pressure conditions—by means of a constant-speed governor. Other control features include: (1) an OVERSPEED TRIP, which closes the throttle if the speed-regulating governor fails to operate and the turbine overspeeds; (2) a BACK-PRESSURE TRIP, which closes the throttle if excessive exhaust pressure is built up; and (3) a MANUAL TRIP, which makes it possible for the throttle to be closed quickly in the event of damage to the turbine or the generator.

A typical ship's service generator turbine control mechanism (fig. 3-12) contains a centrifugal governor which operates a pilot valve controlling the flow of oil to the operating cylinder. In turn, the cylinder piston controls the amount of opening or closing of the turbine nozzle valves, through which steam is admitted to the turbine.

The gear type oil pump and the main speed governor, mounted on the same shaft, are driven through a worm and gear (fig. 3–12). The worm is directly connected to the low-speed gear shaft of the turbine reduction gear; it therefore drives the governor at a speed that is directly proportional to the speed of the turbine.

Speed control is affected by varying the number of nozzle control valves that are open, through the operation of a lifting-beam mechanism; as the beam is moved up and down, the nozzle valves open and close in a predetermined sequence.

Operation of the Main Speed Governor

When the turbine tends to slow down because of an increased load on the generator, the governor weights move inward and cause the pilot valve to move upward, allowing oil to enter the operating cylinder. This causes the operating piston to rise and, through the controlling-valve lever, to raise the lifting beam, opening the nozzle valves and admitting additional steam to the turbine.

The upward motion of the controlling-valve lever causes the governor lever to rise, thus raising the bushing. Upward motion of the bushing tends to close the upper port, shutting off the oil to the operating cylinder; this stops the upward motion of the operating piston. The purpose of this followup motion of the bushing is to dampen the governing action of the pilot valve. Without this feature the pilot valve would operate, with each slight variation in turbine speed, to alternately fully open and fully close the nozzle valves.

When the turbine tends to speed up because of a decreased load on the generator, the governor weights move outward and move the pilot valve downward, opening the lower ports and allowing oil to flow out of the operating cylinder. This action causes the controlling-valve lever to lower the lifting beam, which reduces the amount of steam delivered to the turbine. The downward motion of the con-

trolling-valve lever causes the governor lever to lower; this lowers the bushing. Since the downward motion of the bushing tends to close the lower port, oil is prevented from flowing out of the operating cylinder.

The other three control devices mentioned earlier (the overspeed trip, the back-pressure trip, and the manual trip) all operate to close the throttle and emergency valve. This valve (throttle and emergency valve) is fitted with a device which disengages the valve stem from the hand-wheel operating gear whenever the valve is tripped. This action allows the spring pressure exerted on the top of the valve disk to force the disk down on its seat, closing the valve.

The overspeed trip is operated by the emergency governor (fig. 3–12) mounted on one end of the shaft. It consists essentially of a plunger, which is held in place by a spring. As the plunger moves out, it strikes the trigger; this trips the trip rod and causes the bell crank to move to the right. This motion, in turn, causes the throttle valve to close.

The excessive back-pressure tripping device consists of a bellows and spring arrangement, connected to the exhaust casing of the turbine. If excessive back pressure is built up in the casing, it will overcome the compression of the spring and cause the lever to operate the manual trip. The manual tripping device operates the trigger in the same way as does the emergency governor, closing the throttle. If it becomes necessary to stop the turbine quickly, the manual tripping device should be operated.

Operation of the Generator Turbine

When a generator turbine is started, it is subject to variable expansion resulting from changing temperature and pressure. Therefore, when a turbine is being put in service, a reasonable amount of time should be spent in warming it; and both the speed and the load should be increased gradually.

STARTING THE TURBINE.—When starting a turbine

which is driving an electric generator, the following procedure is recommended:

1. Check the turbine to be sure that all working parts are clean and well oiled. Test all safety devices, where practicable. Trip the overspeed mechanism to ensure that it is functioning properly.
2. See that the oil in the tank is well above the normal operating level.
3. Check the axial setting of the rotating element by means of the rotor position indicator or micrometer, if provided. Log the axial position of the rotors as measured and specify that this is a cold reading.
4. Turn the turbine by hand, using a strap wrench, or other suitable means. The rotor should revolve easily, without noise or grinding.
5. Open the drain ahead of the throttle valve.
6. Leave the drain ahead of the throttle valve open for a short time until the condensate is discharged. See that all turbine drain valves are open.
7. Start the condenser pumps (condensate pumps, air ejector, and circulating pumps).
8. Open the turbine exhaust to the condenser.
9. Bring the vacuum to about 15 inches Hg.
10. Operate the hand pump sufficiently to move the piston of the steam control valves upward, thus admitting steam to the turbine. (The hand pump supplies oil to the bearings at the same time.)
11. Open the throttle valve. As soon as the turbine is started, trip the emergency tripping mechanism by hand to see that it operates properly.
12. Close the throttle valve, reset the tripping mechanism, and reopen the throttle sufficiently to keep the turbine rotor rolling in order to provide oil pressure to the bearings.
13. Admit gland sealing steam to the high-pressure and the low-pressure packing glands.
14. See that there is no indication of rubbing of the

shaft packing or of the rotor, while the rotor is revolving slowly.

15. Gradually open the throttle valve and increase the turbine speed until the low-pressure oil gage indicates approximately 4 psi.
16. Watch the oil temperatures at all bearings and, during the accelerating and warming up period, listen carefully for any rubbing, vibration, or other unusual noise. Determine the cause of and correct any trouble before continuing operation. (A rubbing noise may indicate either a lack of axial clearance in one direction, or packing rubbing on the shaft. If the axial clearance is incorrect, the rotor position should be shifted by changing the thickness of the thrust bearing liner. If the packing rubs, examine it and refit.)
17. Cut in the circulating water to the oil cooler when the oil temperature at the bearings reaches approximately 110° F., start the circulation of water in the oil cooler, regulating the flow of cooling water to suit conditions.
18. Increase the turbine speed to operating speed when the unit is satisfactorily warmed up.
19. Close the turbine drains, and increase the vacuum as much as conditions will permit.
20. As soon as normal speed is reached and the machine is controlled by the speed governor, open the throttle wide and retest the operation of the emergency tripping device.
21. Close the throttle valve about ½ turn; this will prevent sticking of the throttle valve.

OPERATING THE TURBINE.—The following steps should be observed during the operation of a turbine:

1. Check the temperatures to ensure that the water is circulating in the oil cooler.
2. Check to ensure that air is circulating in the generator and exciter.
3. See that the oil pump delivers an ample supply of

oil to the bearings and to the hydraulic cylinder. The oil level must be kept between the limits on the oil level gage.

4. At periodic intervals, determine the temperature of the bearings. A satisfactory running temperature of the return oil is approximately 150° F. The maximum temperature should not exceed 180 ° F. The temperature rise of oil through any bearing should not exceed 50° F. A log should be kept of bearing oil temperatures and pressures.
5. Where a micrometer is provided for measuring the axial position of the turbine rotor, record this clearance. When comparing readings to determine the thrust bearing wear, be sure to compare the readings obtained under the same conditions of operation.
6. Adjust the valves, as required, in the gland-sealing steam lines. A pressure from ½ to 2 psi gage is sufficient to maintain a proper vacuum.
7. Inspect the lubricating system and make certain that all parts are functioning properly.
8. Check the vacuum to see that the condenser is operating properly.
9. Watch for oil, steam, or water seepage. (If any occurs, correct the condition which causes it.)
10. Check for smoothness of operation and freedom from unusual noise.
11. Check for correct designed operating conditions by observing the readings on the steam and oil pressure gages.
12. Once each watch, when load conditions permit, partially close the throttle valve to make certain that the valve stem moves freely through its packings.
13. Do not keep the turbine in service unless it is known that the safety devices are in condition to operate, except in cases of extreme emergencies.
14. Once each watch, and more frequently on new in-

stallations, inspect the oil strainer baskets used during the operating procedure. They should be cleaned frequently by switching the oil flow to the other baskets, not in use. If steel particles are attached to the magnets, inspect the gears for lack of oil. If particles of babbitt are found in the screen, inspect the bearings.

15. Operate the hand nozzle valves, when required, either in the fully closed or fully open position.
16. Keep the exterior of the unit free from dust, dirt, oil, and water.

SECURING THE TURBINE.—When a generator turbine is to be secured, the procedure is as follows:

1. Shift the load to another machine by reducing the load on the generator.
2. Trip the generator circuit breaker.
3. Close the throttle valve by striking the trip latch of the overspeed tripping mechanism.
4. Operate the hand oil pump until the rotor stops revolving; this will avoid unnecessary bearing wear.
5. Shut off the steam supply to the packing.
6. Shut off the water to the oil coolers.
7. Close the stop valve ahead of the throttle valve and open the drain ahead of the throttle valve to relieve pressure and to drain the line.
8. Open drains on the throttle valve, the turbine casing, and the steam-seal line.
9. Operate the air ejector for several minutes to draw out all vapor and water from the turbine and thus prevent internal corrosion.
10. After the condensate has run out and the casing has cooled to engineroom temperature, close all the drains and secure the exhaust valve, if provided.

When the turbine is shut down, even for a short time, take every precaution to guard against steam bleeding into the turbine casing. When the unit is restarted after a brief shut-down period, bring it up to speed with the same care

that is exercised when starting a cold turbine. In addition, make periodic inspections of the tooth contact of the pinions and the gear, and the associated oil spray nozzles. An inspection cover located over the gear mesh is provided for this purpose on some units.

ACCESSORIES

As an MM2 you must be familiar with turbine accessories such as indicators, meters, locking devices, and coupling devices. The section which follows deals with the accessories you will be expected to use aboard ship.

Rotor Position Indicator

The rotor position indicator at the forward end of the cruising turbine is shown in figure 3–13. (The rotor position indicators used with high- and low-pressure turbines are essentially the same as those used with cruising turbines.) Before the position of the rotor is checked, the screw must be backed off to allow the plunger to be pushed into the contact end of the rotor. While the plunger is in contact with the rotor, move the indicator plate until it contacts the pointer. The reading obtained at that point indicates the position of the rotor. The indicator should be inspected periodically, during either ahead or astern operation, to make sure that the rotor is in the range between the two end positions on the indicator plate. The indicator is initially adjusted with the rotor blocked against the forward thrust plate, to give a reading of 0.000–IN. ROTOR FWD. This adjustment should be restored after any work on the rotor. The readings between 0.000–IN. ROTOR FWD and 0.000–IN. ROTOR AFT indicate the running thrust clearance.

Differential-Expansion Indicator

The low-pressure turbine is also provided with a differential-expansion indicator (fig. 3–14), located at the after end of the turbine. This indicator is used to deter-

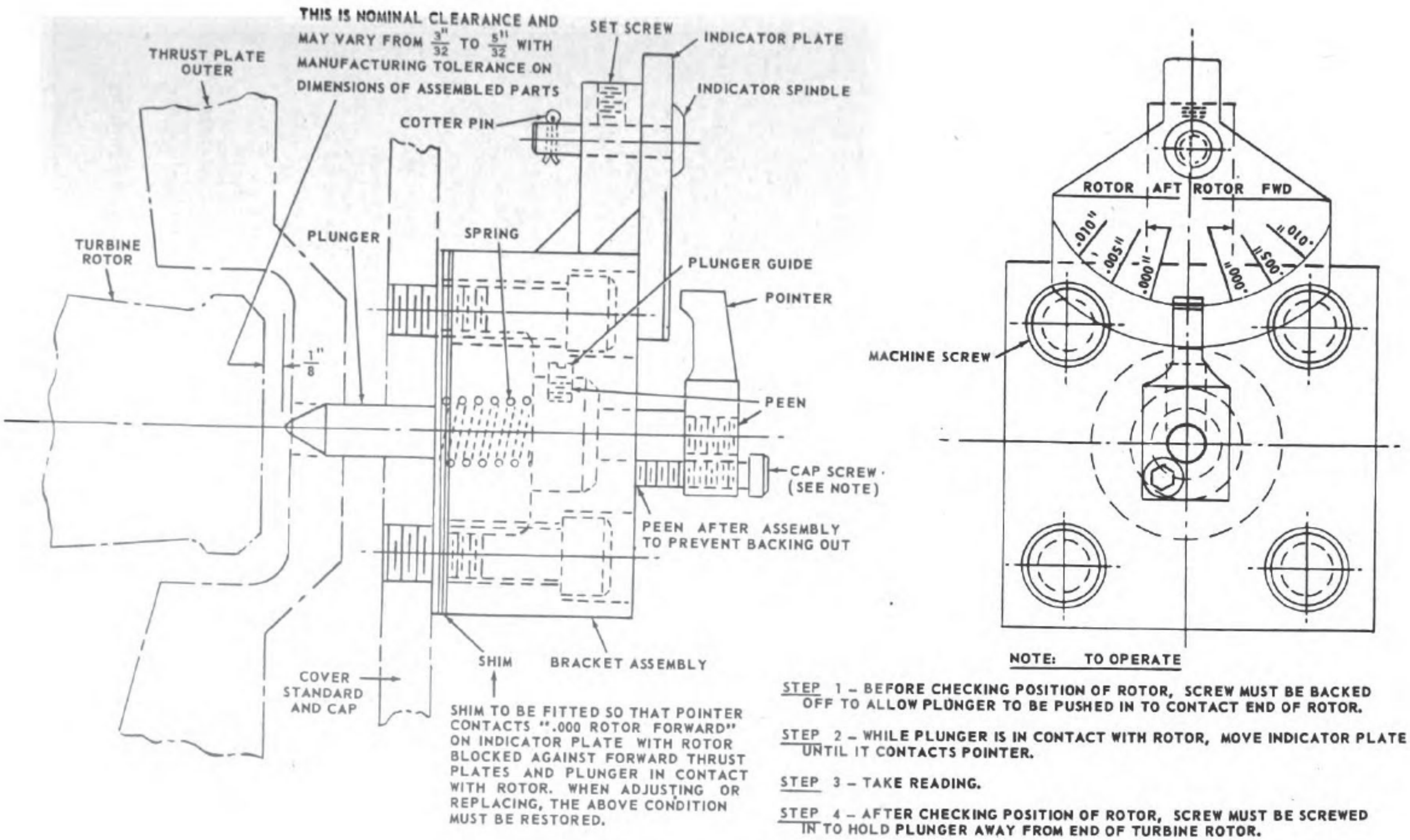
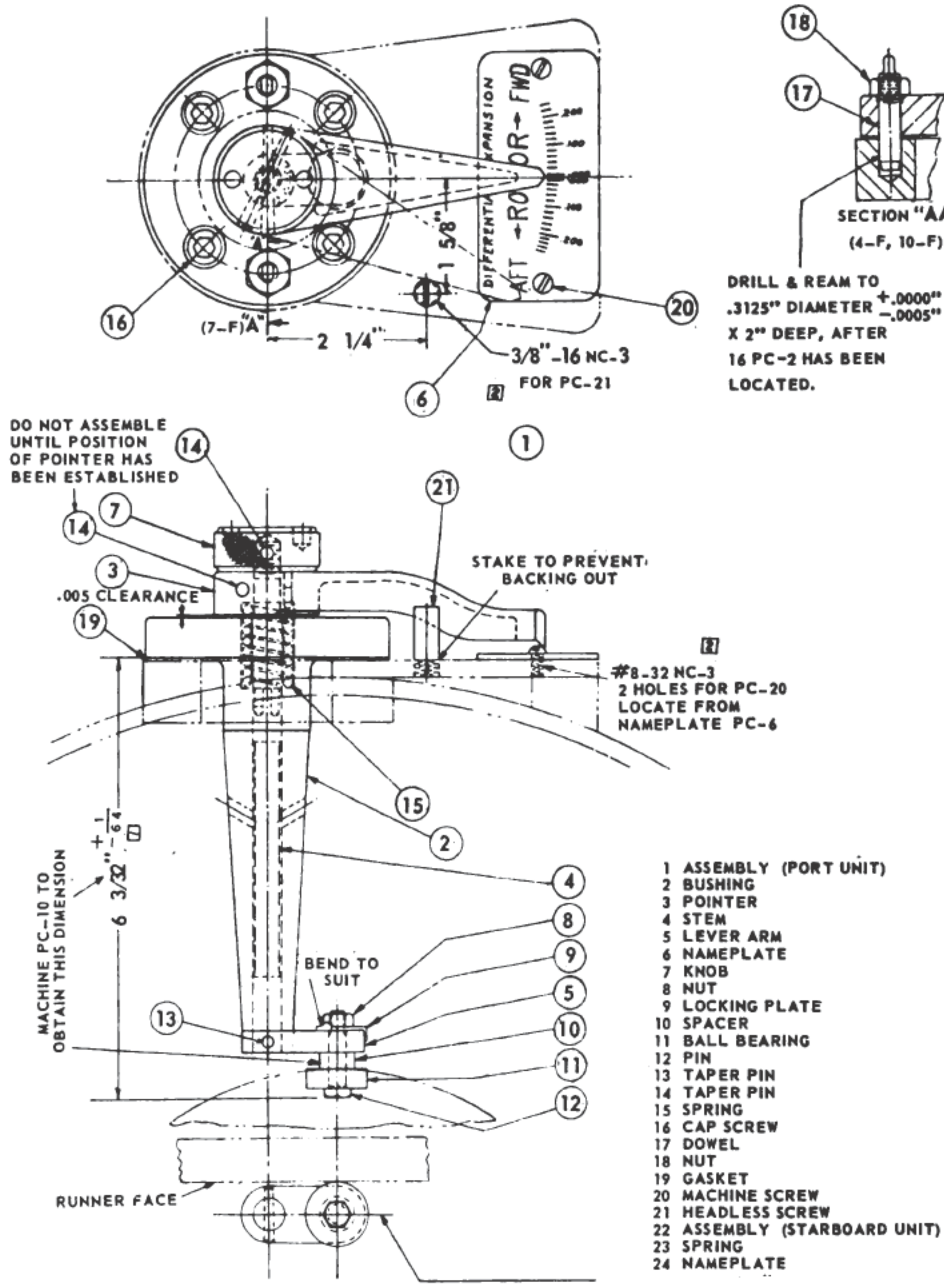


Figure 3–13.—Rotor position indicator.



1 ASSEMBLY (PORT UNIT)
2 BUSHING
3 POINTER
4 STEM
5 LEVER ARM
6 NAMEPLATE
7 KNOB
8 NUT
9 LOCKING PLATE
10 SPACER
11 BALL BEARING
12 PIN
13 TAPER PIN
14 TAPER PIN
15 SPRING
16 CAP SCREW
17 DOWEL
18 NUT
19 GASKET
20 MACHINE SCREW
21 HEADLESS SCREW
22 ASSEMBLY (STARBOARD UNIT)
23 SPRING
24 NAMEPLATE

Figure 3-14.—Differential-expansion indicator, low-pressure turbine.

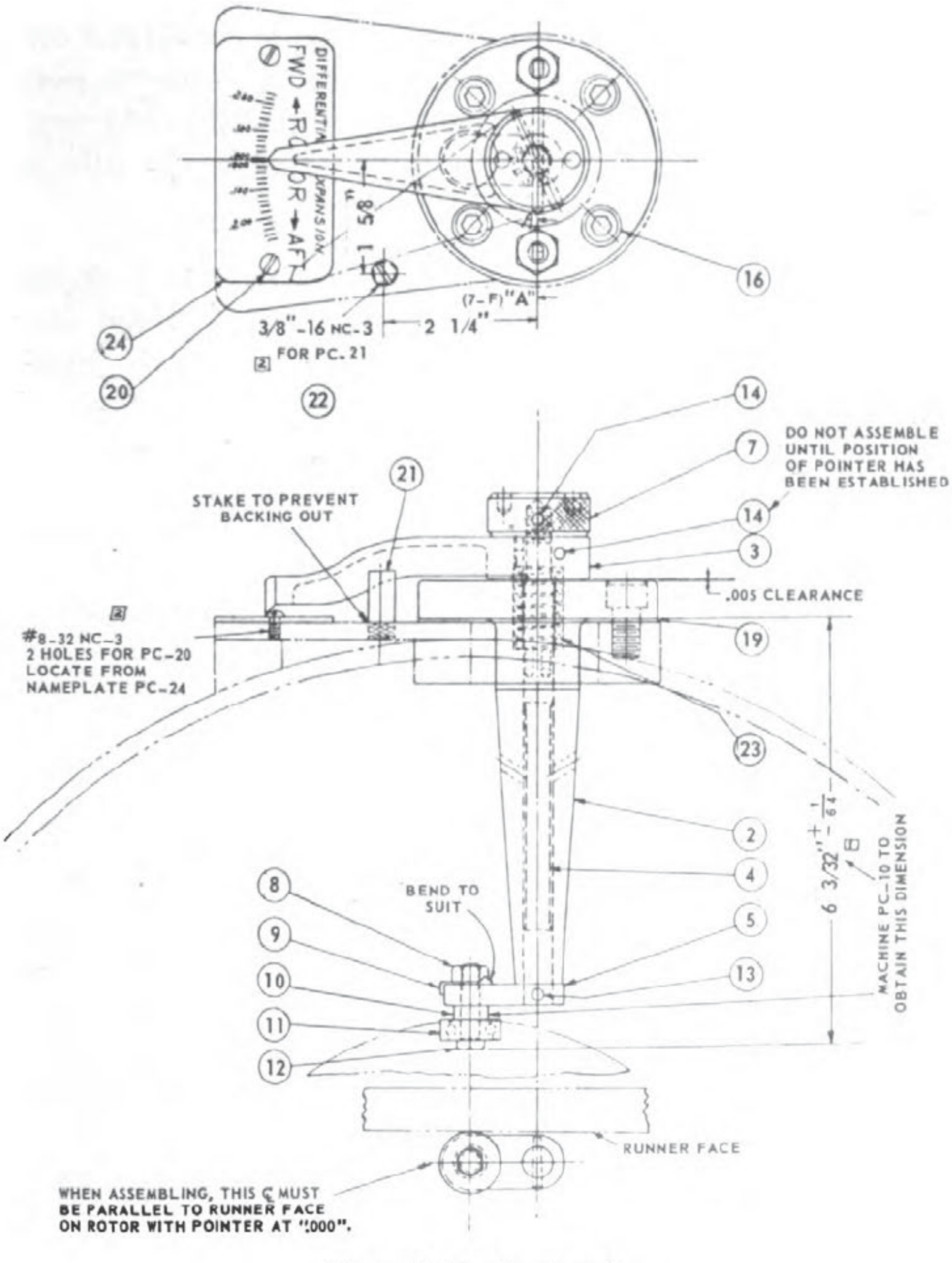


Figure 3-14.—Continued.

mine the relative position of the rotor, with respect to the casing, resulting from reversals in direction of rotation and changes in temperature. This indicator is used by turning the knob (7) to bring the ball-bearing roller (11) into contact with a running face which is machined on the turbine rotor. The position of the rotor, with respect to the casing, is then indicated by the pointer (3) on the indicator plate (24). The pointer is held in the idle position by the torsion spring (23).

CAUTION: The indicator shown in figure 3–14 is initially adjusted to give a reading of "0.000 inches ROTOR FW'D" when the rotor is blocked against the forward thrust-bearing plate. The maximum readings of approximately ".280 inches AFT" and ".240 inches FW'D," designated on the indicator plate, are the maximum expected movements of the rotor before rubbing will occur between the bucket-cover edges and the nozzle diaphragms. (These figures pertain to indicators installed on the DL–2 and DL–3 ships.)

Differential-Expansion Alarm

In addition to the differential-expansion indicator, the low-pressure turbine is provided with a differential-expansion alarm. This alarm operates automatically to warn operating personnel that differential expansion has caused a change in the relative positions of the rotor and the casing sufficient to reduce the axial clearance below a safe operating value.

Thrust Bearing Clearance Indicator

Figure 3–15 illustrates a thrust clearance indicator, or gage, which measures the end play permitted by the main thrust bearing. The end play of the main gear can be determined with the thrust bearing indicator, while under way, by turning the propeller over slowly, alternately in

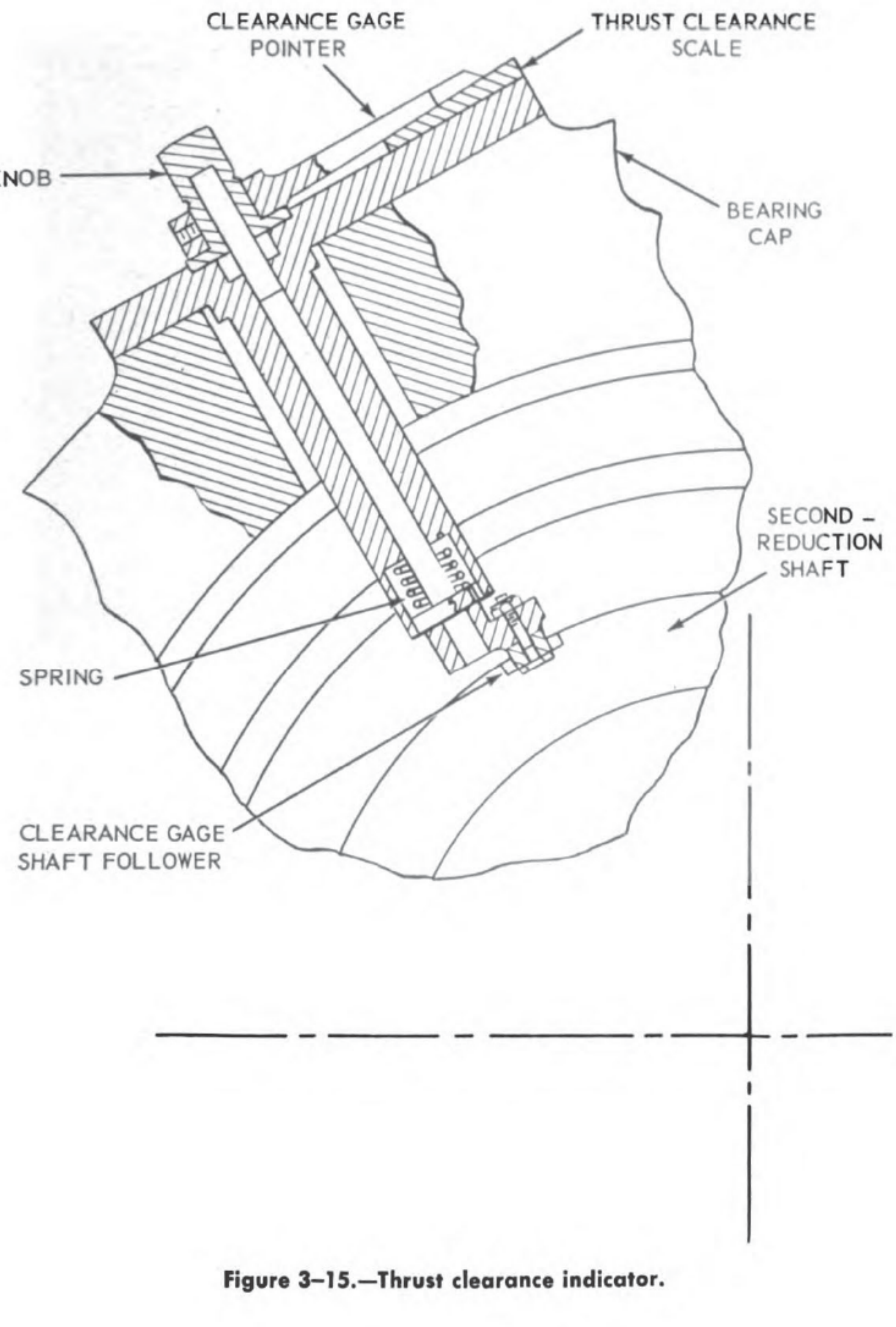


Figure 3–15.—Thrust clearance indicator.

the ahead and astern directions, and taking indicator readings.

The thrust clearance indicator is mounted on the cap of the forward main-gear bearing. The mechanism consists of a pointer, mounted on a spring-loaded shaft, to indicate a position on the clearance scale. The indicator is read from a position 45° above the joint, on the inboard side of the forward main-gear bearing cap. The shaft which mounts the pointer also mounts a short bell crank at the end of which is affixed a small ball bearing. Rotation of the knob (fig. 3–15) against the spring pressure forces the ball bearing (clearance gage shaft follower) against the end of the main-gear shaft. At this position the pointer will indicate the location of the shaft within the thrust bearing. The pointer is set to read zero when the thrust collar stands midway in the thrust-bearing clearance.

CAUTION: The spring load is provided to prevent the ball bearing from riding against the end of the shaft, except when the indicator is in use. When taking readings, it is important that the operation be accomplished in as little time as possible to prevent wear of the bearing.

Gear Shaft Position Indicator

This indicator, mounted on the after main-gear bearing cap, consists of a small disk which is bolted to the after end of the bearing cap and aligned with a ridge machined on the main-gear shaft. This indicator shows the proper axial location of the gears in the casing. In addition, it gives indication of excessive wear of the main thrust-bearing shoes.

Propeller Locking Device

The turning gear is equipped with a locking device which can be used when it becomes necessary to lock a propeller against rotation, while under way. (Since the turning-gear mechanism was discussed in *Machinist's*

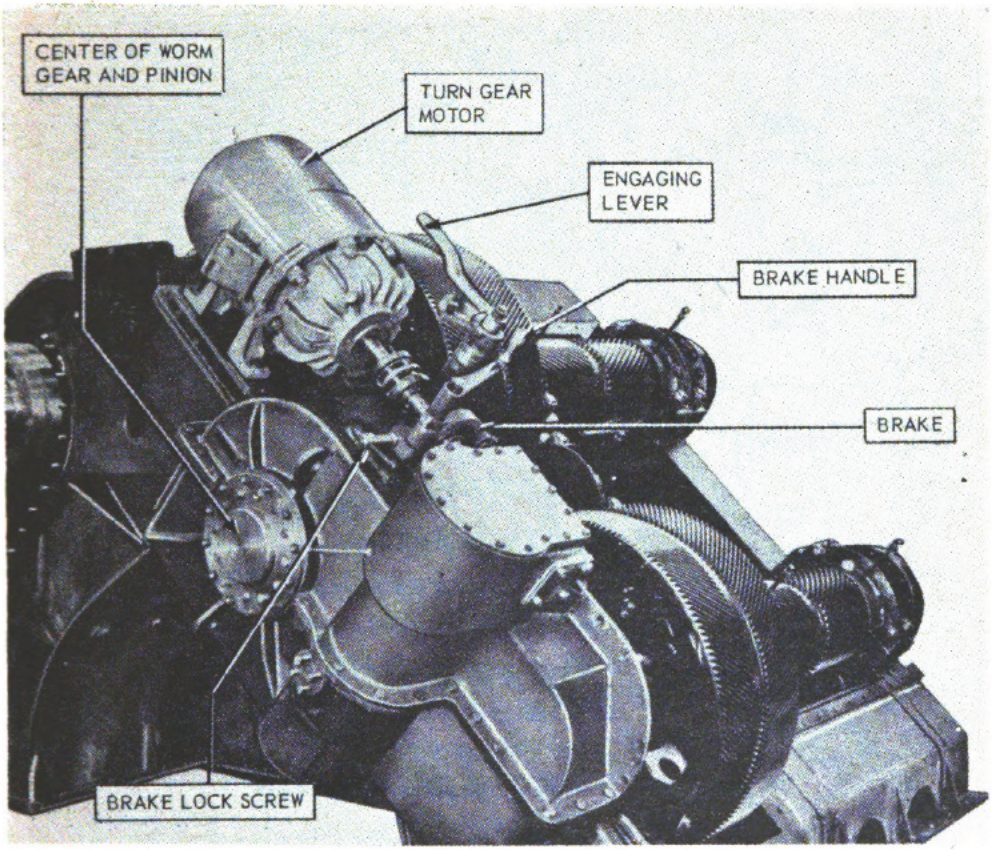


Figure 3–16.—Main reduction gear after end, high-pressure side, showing turning gears and propeller locking mechanism.

Mate 3, NavPers 10522, it will not be covered in this section. Additional information concerning the purpose and principles of operation of turning gears may be obtained from manufacturers' technical manuals.)

The propeller-shaft locking device, located at the top of the turning-gear casing (fig. 3–16), consists of a brake and drum mounted on the first-reduction worm shaft. In this arrangement, shown in figure 3–17, a drum (1) is mounted on the first-reduction worm shaft (2). In addition, a pair of scissor-type clamp jaws (3 and 4) are mounted around the drum; they are hinged together by a pin (5) through the anchor support block (6). An adjustable screw (7) is arranged below the lower-clamp jaw (4) to support it in such a position that, when released, the jaw will not drag on the drum. A screw shaft (8) has

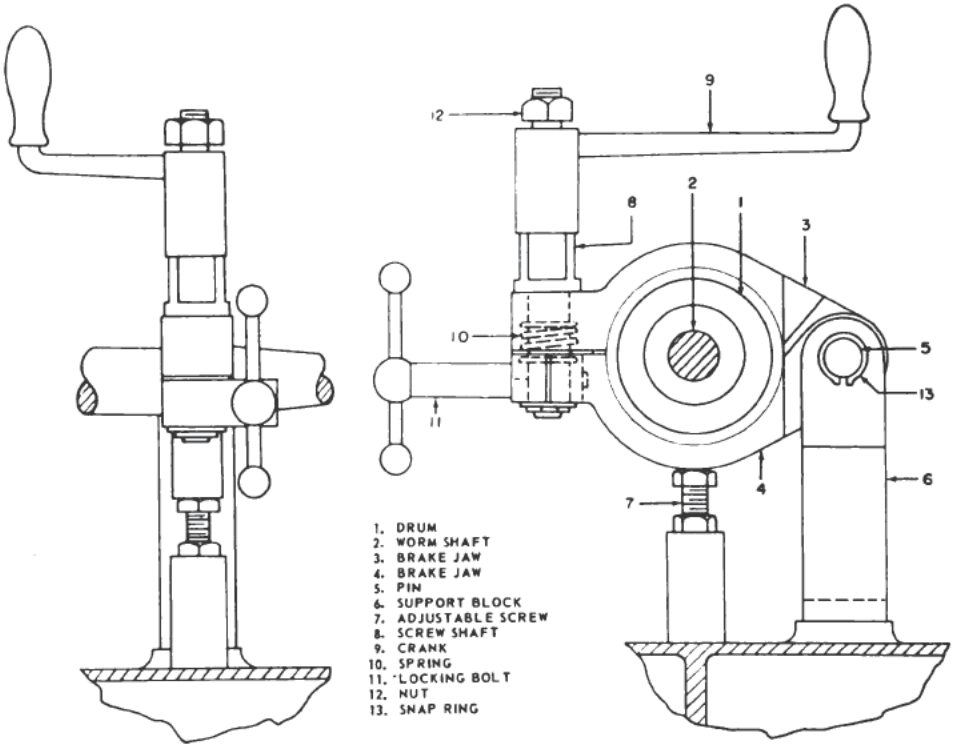


Figure 3–17.—Propeller-shaft locking device.

threads at its lower end which screw into the lower-clamp jaw (4). When the crank handle (9) is turned in a clockwise direction, the screw shaft draws the upper-clamp jaw toward the lower-clamp jaw and tightens the jaws around the drum. This brake stops the rotation of the worm-gear shaft. A spring (10) is mounted between the clamp jaws so that when the screw (8) is released, the clamp jaws are forced open and lift the upper jaw and drop the lower jaw free from the drum. Another screw (11) is provided to clamp the screw (8) in either the locked or unlocked position so that accidental engaging or disengaging of the brake jaws cannot occur.

Revolution-Counter Drive

The revolution-counter drive (fig. 3–18) is mounted on the low-pressure side, after end, of the upper-intermediate quill shaft. It is driven by an adapter gear bolted to the end of the intermediate shaft.

The casing of the revolution-counter drive is a bronze

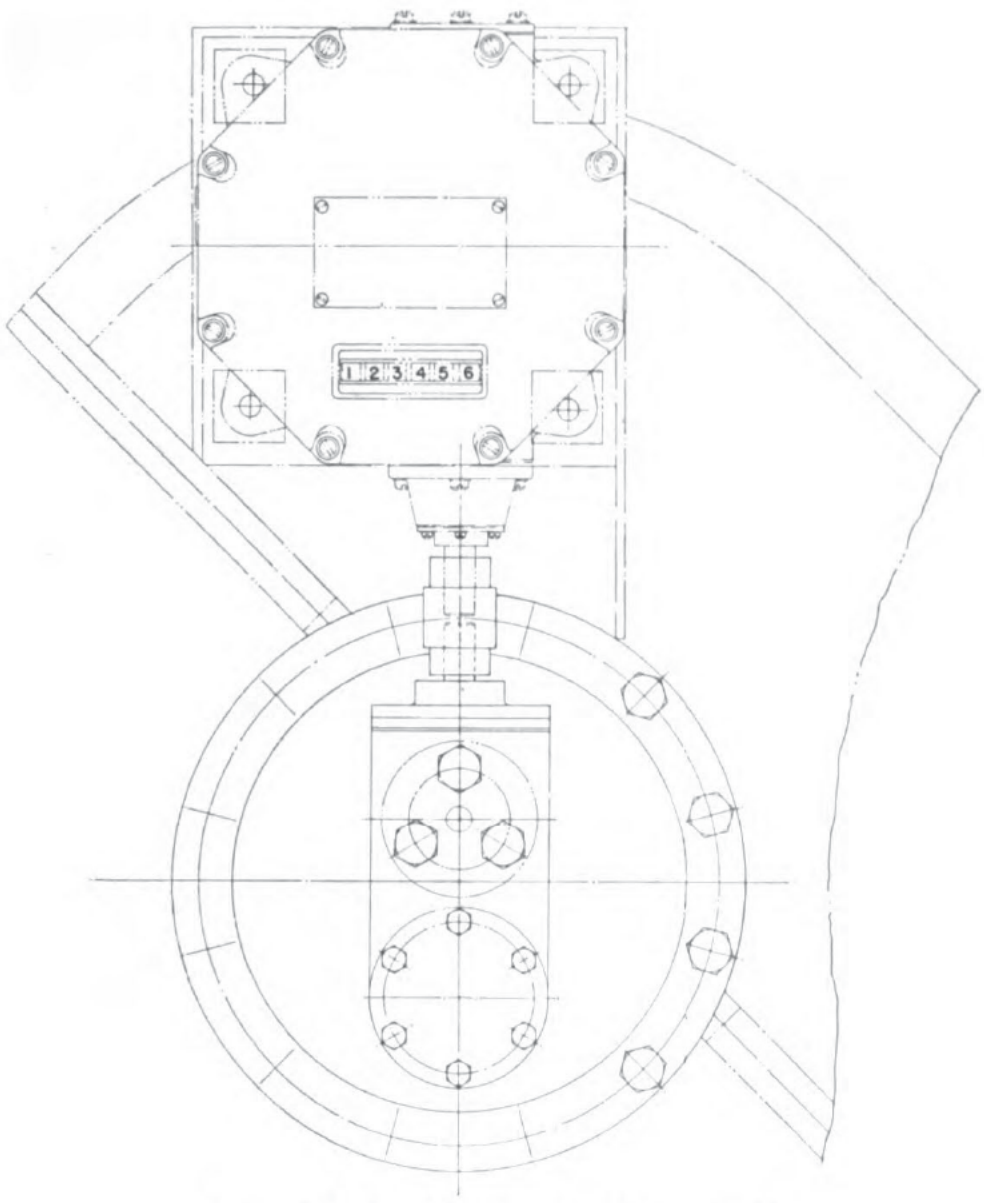


Figure 3–18.—Revolution-counter drive assembly.

casting. In this casing are mounted the gear clusters, each supported by ball bearings. The pinion (A) is bolted directly to the end of the upper-intermediate shaft and drives gear (B), mounted on the same shaft with pinion (C), which, in turn, drives the gear (D) and the spiral bevel pinion (E). The spiral gear (F) is the second-reduction gear and drives the vertical output shaft, connected to the revolution counter. The latter is mounted

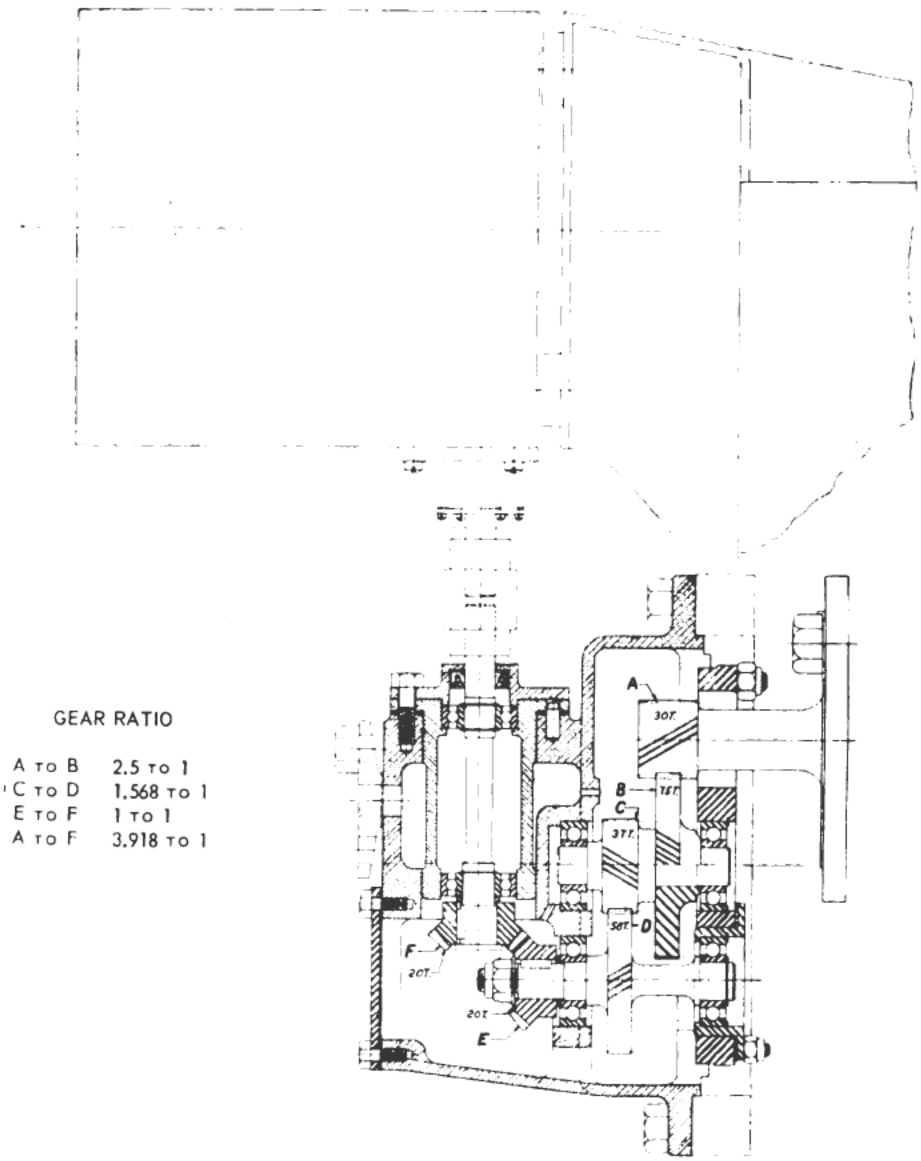
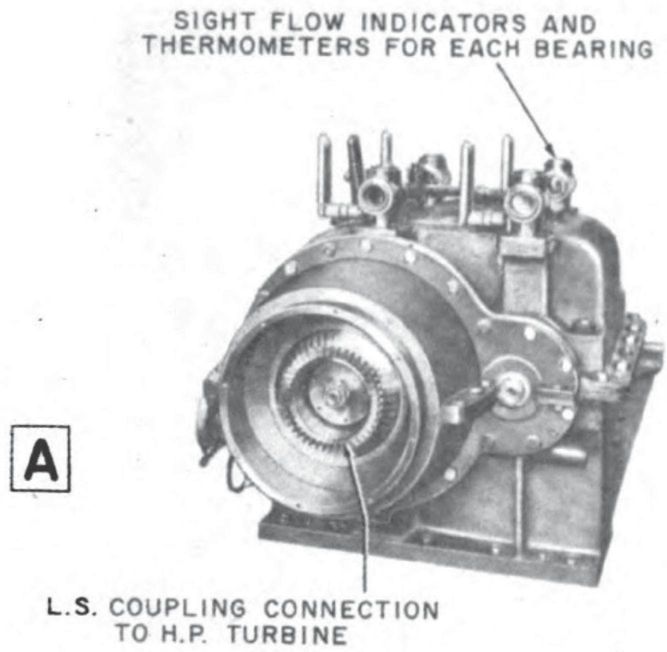


Figure 3–18.—Continued.

directly above the counter drive on the coupling guard of the main gear. The scale may be read by looking directly forward at the after end of the main gear.

Coupling and Disconnect Device

The cruising reduction gear is equipped with a mechanism which permits the disconnection of the flexible coupling between the cruising gear and the main high-pressure turbine, and provides a means for locking the cruis-



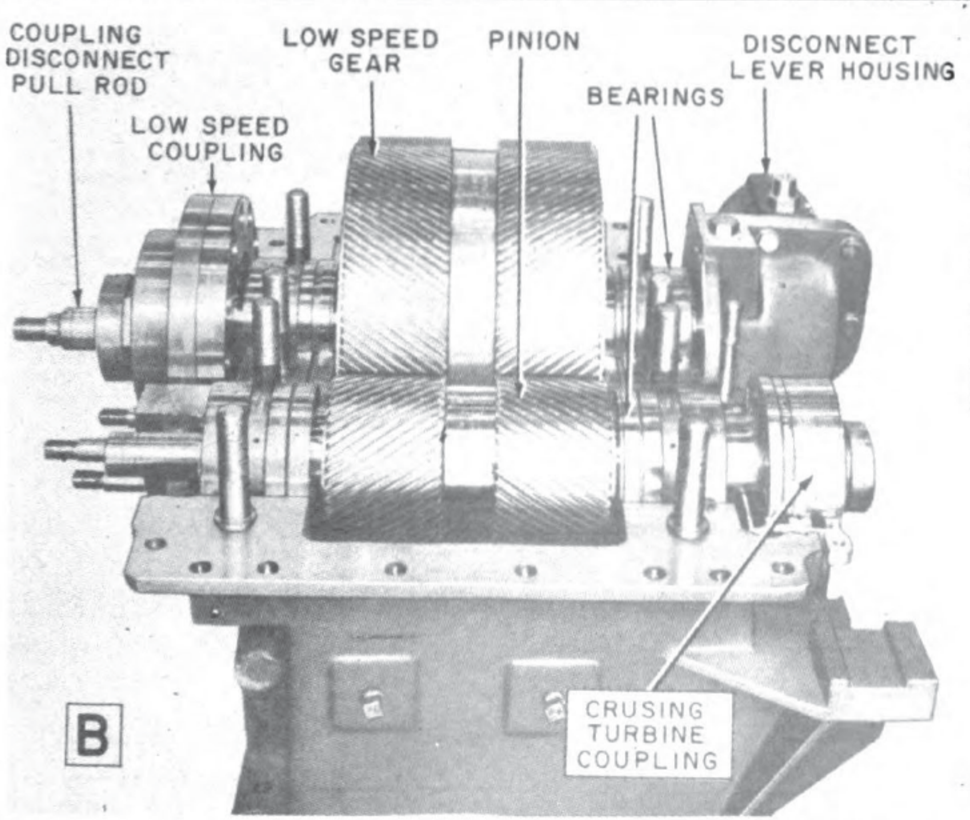
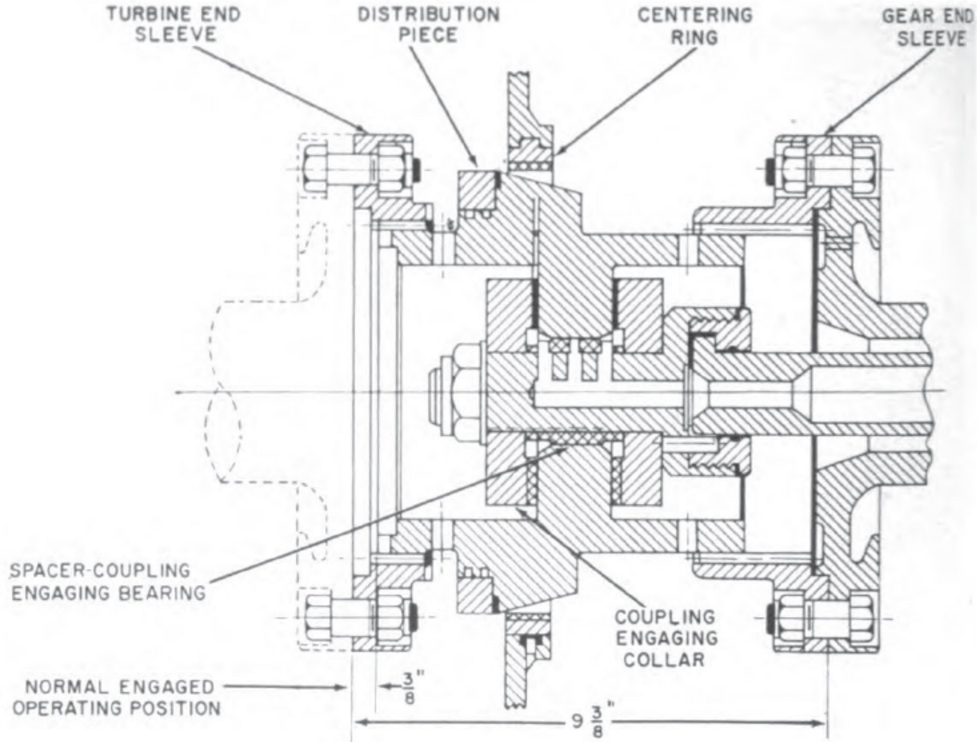
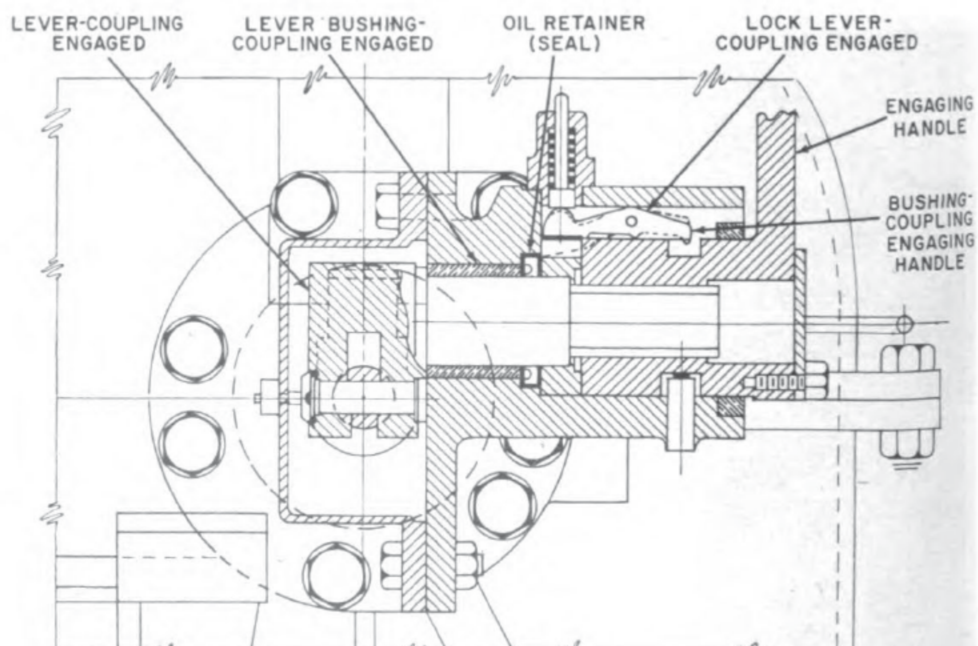


Figure 3–19.—(A) Assembled cruising gear, after end, showing the disconnect first-reduction coupling; (B) cruising gear, cover off, showing bearings, pinion, and gear.



A



B

Figure 3–20.—Sectional views of the disconnect-device assembly.

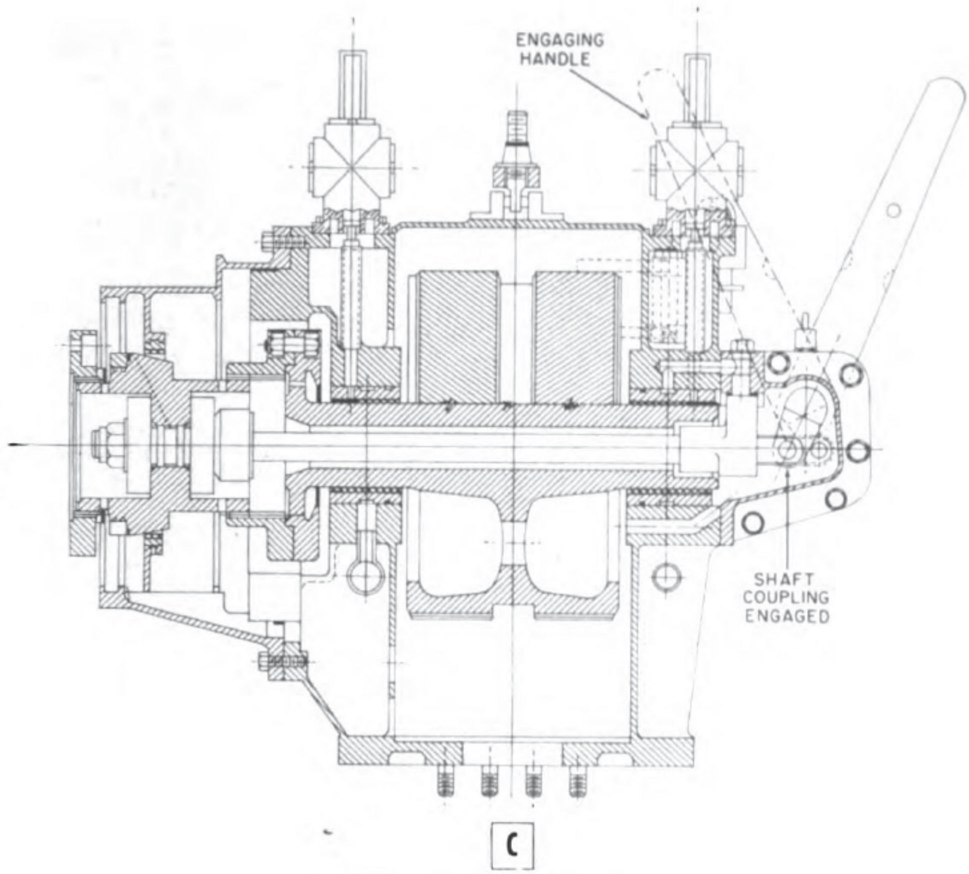


Figure 3–20.—Continued.

ing-turbine rotor against rotation, after the coupling has been disconnected. This is an emergency feature, used in the event of damage to the cruising turbine which necessitates removing the cruising turbine from operation without taking the main turbines out of service.

Figures 3–19(A) and 3–19(B), two views of the cruising reduction gear, will serve to give you a better understanding of the operation of the coupling and disconnect device.

The low-speed shaft of the cruising gear is coupled to the forward end of the high-pressure turbine by a flexible-type coupling, consisting of a distance piece meshing with a sleeve on the gear shaft, and a sleeve on the high-pressure turbine shaft (fig. 3–20A). The gear-end sleeve has longer teeth than the turbine-end sleeve (fig. 3–20A);

thus the distance piece is always kept in mesh with the gear.

A double-thrust face and a journal surface are provided in the bore of the distance piece, into which are assembled a double-thrust bearing and a journal bearing (fig. 3–20A). A pull-rod (fig. 3–20C) connects to these bearings, and is used to locate the distance piece either in the engaged or disengaged position. (Lubrication is also furnished to the thrust bearings through the drilled pull-rod.)

An alignment bearing (fig. 3–30A), or centering ring, is mounted in the coupling guard to maintain alignment of the coupling distance piece with the high-pressure turbine sleeve, when the coupling is disconnected. This permits easy re-engagement of the coupling. The distance-piece teeth at the turbine end and the turbine sleeve, have tapered teeth. Re-engagement of the coupling is possible without jogging the rotors to position the teeth because the tapers allow the teeth to find their position automatically as the distance piece is moved by the lever (fig. 3–20B).

The disconnecting mechanism is located at the forward end of the reduction-gear casing. This mechanism consists of a double-lever arrangement. The smaller lever, pinned to the end of the pull rod, is machined integral with a shaft which is supported in a bushing. The end of the shaft is splined to match the engaging lever (fig. 3–20B). Another bearing support for the assembly is a bushing which contacts the hub of the engaging lever. A seal (fig. 3–20B) prevents leakage of oil from the casing. It is supported by an enclosed fabricated casing, split vertically to permit disassembly. A lock lever (fig. 3–20B) permits the coupling to be locked when the engaging lever is removed from the assembly.

MAINTENANCE OF TURBINES

The maintenance of turbine installations is as important as their proper operation. If proper maintenance pro-

cedures are followed, abnormal conditions may be prevented. As an MM2, you will probably be concerned with major adjustments, as well as measurements, of turbines. In addition, you must know how to fit carbon packing rings to turbines.

Major Adjustments of a Turbine

In all propulsion turbines installed on ships in the Navy, there are two major adjustments: the fixing of the proper radial and axial positions of the rotor. The radial position of the rotor is maintained by the main bearings, and the axial position by the thrust bearings.

In impulse staging, the radial clearances are large and have no effect on the efficiency of the turbine. The axial clearances also, within the limits permitted by the design of the turbine, will have almost no appreciable effect on the turbine efficiency, because the same pressure exists on both sides of the moving blades; as a result, there is no tendency for the steam to bypass the blades. In impulse staging, axial clearances are kept small in order to reduce the length of the rotor and the casing.

The clearances in all shaft and diaphragm packings are small, and they will be altered if the position of the rotor changes (as a result of wear, either of the journal or of the thrust bearings). This change results in reduced efficiency of the turbine because of the steam leakage by the glands, and repairs will eventually be necessary.

The major reason for maintaining a turbine rotor in its proper position is to prevent damage to the turbine. If the rotor touches the casing at any time, because of failure of the thrust or journal bearings while the turbine is in operation, damage will result and it will be necessary to lift the turbine casing for repairs. The turbine parts that are particularly subject to damage, because of close clearances involved, are the rotor blading, diaphragm packing rings, shaft packing rings, and oil deflector or oil seal rings.

RADIAL POSITION OF ROTOR.—Bridge gages are supplied

with each installation for use in detecting any change, resulting from wear of the bearings, in the vertical and horizontal positions of the turbine rotors (when cold). To use one of these gages, remove the top bearing cap and carefully clean the shaft journal and the flange of the lower half of the bearing housing. Do not remove any of the metal from the joint. Then carefully place the gage over the journal so that the ends of the gage rest on the cleaned housing surface, and the dowels of the gage rest in the holes in the horizontal joint at the centerline of the bearing, as shown in figure 3–21. (There are a pair of pins located next to the dowels in which the gage rests when in place.) With feelers, measure the clearance between the journal and the top and side reference surfaces of the bridge gage. The original clearance is stamped on the bridge gage, as is the name of the bearing on which the gage is to be used (for example, H.B.Stbd. 0.0625 Fwd. Bearing).

The difference between the reading stamped on the

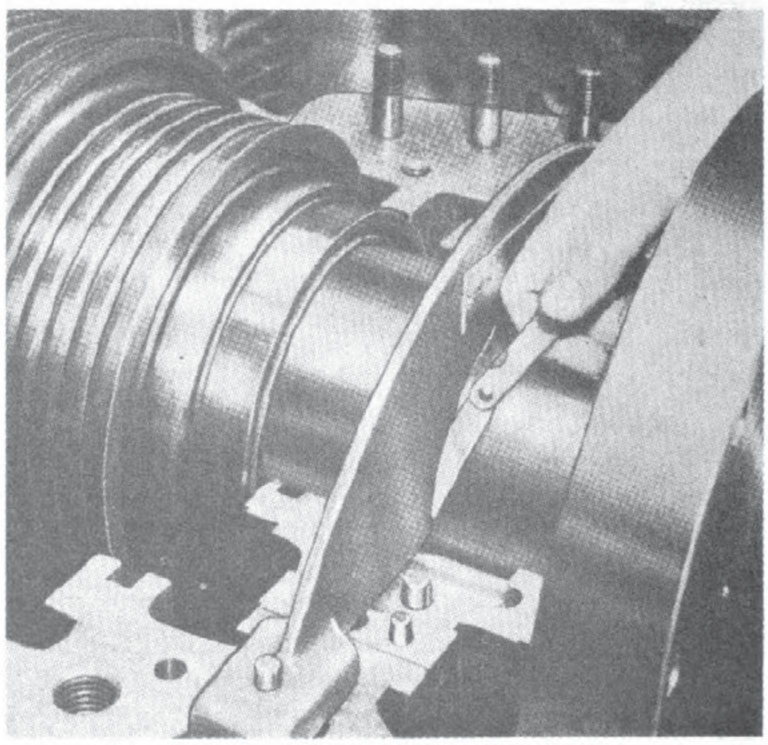


Figure 3–21.—Taking a horizontal measurement with a bridge gage.

gage and the reading obtained with the feelers is the amount that the shaft is above or below its proper position. This difference should be within a few thousandths of the figure stamped on the gage. Data on allowable tolerances can be obtained either from the manufacturer's technical manual or from chapter 40 of BuShips *Manual.*

The thickness of the oil film between the journal and its bearings will affect the reading. For this reason, if practicable, bridge-gage readings should be taken after the oil has been shut off for 24 hours. If it is impracticable to

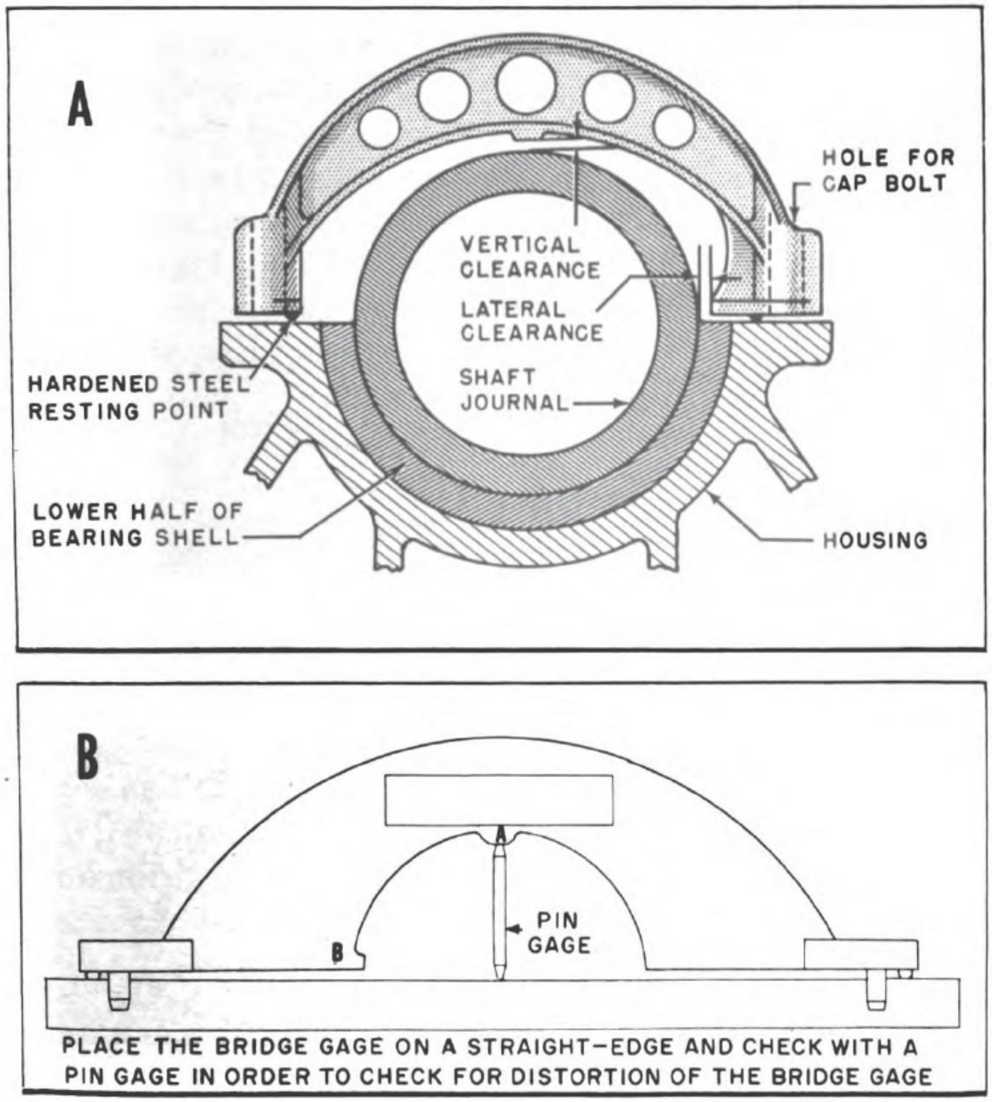


Figure 3–22.—(A) Bridge gage, and (B) checking bridge gage with pin gage.

wait 24 hours after shutting off the oil supply, the interval between shutting off the oil and taking the readings should be as long as possible.

Before a bridge gage, shown in figure 3–22A, is used, it should be examined to see that it has not been damaged in any way. Most ships are provided with pin gages (fig. 3–22B) to check for possible distortion of the bridge gage. Bridge-gage readings should be taken once each quarter, and a permanent record should be kept of all readings taken.

Where turbine bearings are fitted with depth gage micrometers, the micrometer readings may be substituted for the bridge-gage readings. In this case (fig. 3–23), the depth gage spindle is inserted into the depth gage well until the bridge of the gage rests evenly on the reference boss; the knurled handle of the micrometer is then turned until the spindle touches the journal. The reading is taken and compared with previous readings. The original reading for each bearing is stamped on the reference boss.

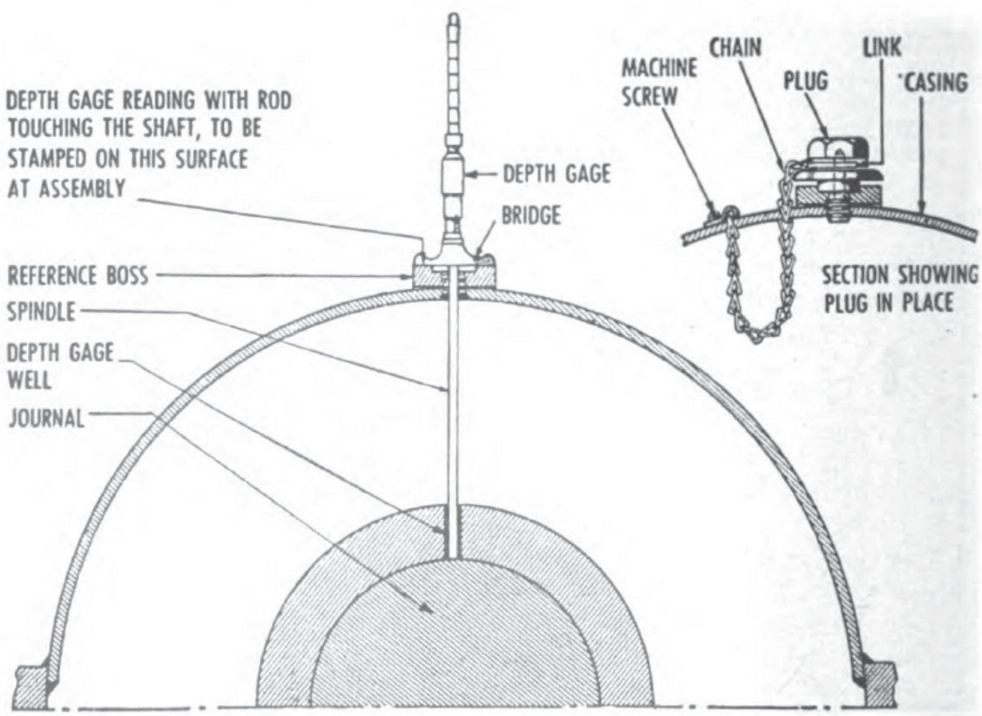


Figure 3–23.—Bearing-wear micrometer depth gage.

Depth gage readings should not be taken while the turbine is in operation.

For measuring reduction gear bearings, an ordinary (simple) micrometer is generally used. The bearing shell is removed and its thickness measured at both ends, opposite scribe marks at points 1¼ inches from the ends of the shells. Comparison of readings with those previously taken indicates the bearing wear.

AXIAL POSITION OF ROTOR.—The axial position of a turbine rotor is maintained by means of a thrust bearing, usually of the pivoted segmental or Kingsbury type. With this type bearing, the axial position of the rotor is adjusted by machining from the filler piece or liner, or by adding shims thereto. (Detailed information on thrust bearings can be obtained from either the manufacturer's technical manuals or from *Machinist's Mate 3,* NavPers 10522.)

The axial clearance instruments consist of the rotor position micrometer and the axial clearance micrometer. The rotor position micrometer is shown in figure 3–24. It is used on old type turbines, while they are in operation, to determine the axial position of the rotor and the amount of thrust-bearing wear.

The principal parts of the rotor position micrometer are: (1) the spindle, with spindle head attached; (2) the body, attached directly to the turbine casing; (3) the index wheel, which is threaded to the body and is graduated to read axial movement in thousandths of an inch; (4) the feeler plate; and (5) the spring. The spindle is cut away at the end, leaving only a half section.

With the spindle turned as shown in figure 3–24A the protruding half section rests against the turbine rotor; when it is turned 180°, as shown in figure 3–24B, it rests against a projection of the casing. The spindle is kept from turning, when not pulled all the way out, by means of two projecting lugs (on the spindle), a short distance from the spindle head. These lugs slide in slots machined on the inner diameter of the body. When the spindle is

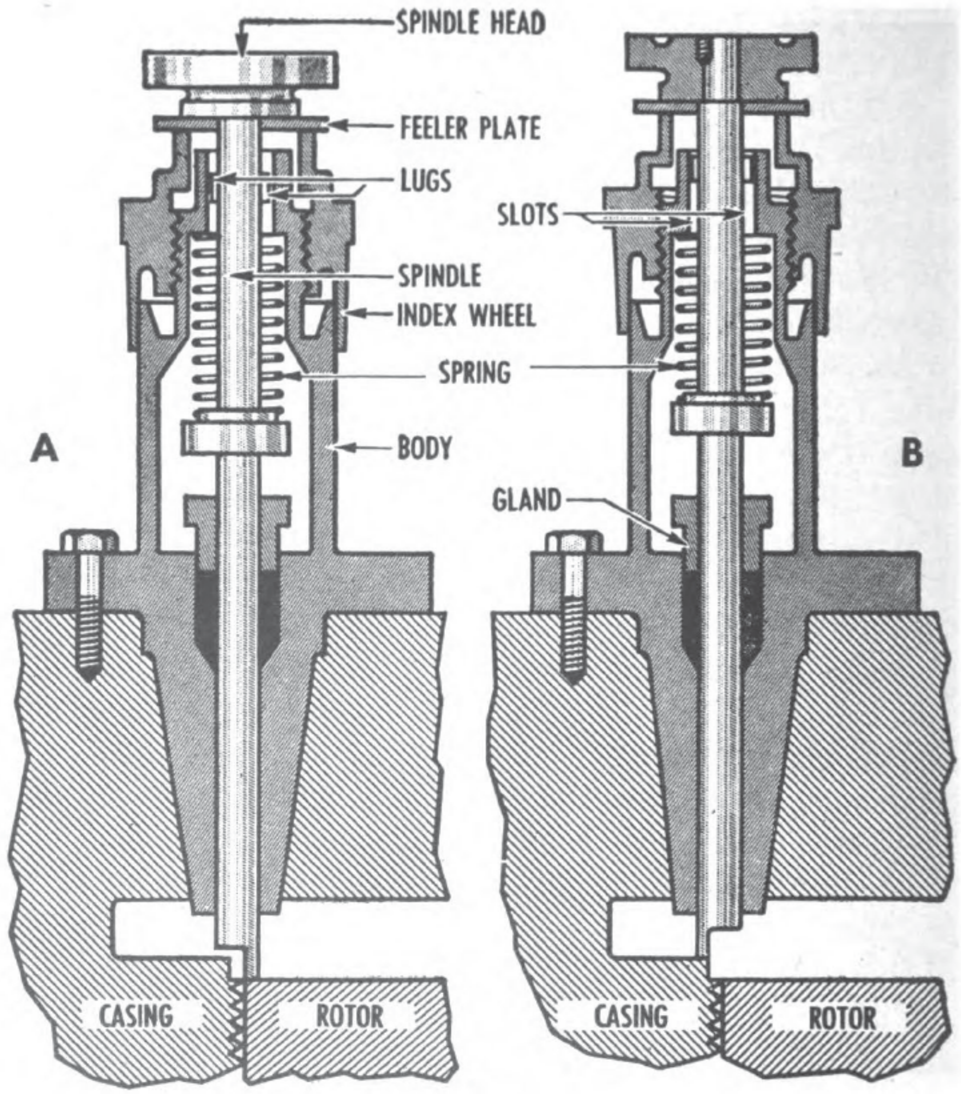


Figure 3–24.—Rotor position micrometer.

not resting against the casing or rotor, the feeler plate is held tightly between the index wheel and the spindle head by the compression of the spring. However, when the index wheel is advanced until the spindle touches the casing or rotor, the spindle head and index wheel separate and allow the feeler plate to become free. The purpose of the feeler plate and spring arrangement is to enable the operator to know when the spindle is just touching the rotor or casing. In addition, the danger of seriously wearing or breaking the spindle end on the rapidly turning

rotor is avoided, because the maximum pressure that can be applied to the spindle is that which can be exerted by the spring.

To take a reading, back the index wheel off sufficiently to hold the spindle away from the turbine rotor. Then turn the spindle so that it can rest against the rotor. Then advance the index wheel slowly until the feeler plate is just free (fig. 3–24A). With the feeler plate just free, take and record the reading on the micrometer. Next, back the index wheel off, pull out the spindle, and turn it 180° so that it can rest against the casing. Again advance the index wheel until the feeler plate is just free and take another reading (fig. 3–24B). The difference between the two readings, taken with the rotor position micrometer, gives the relative position of the turbine rotor and casing. (The reading is taken on the casing as well as on the rotor because a single reading on the rotor would not take into account the wear in the end of the spindle.)

Readings are carefully taken and recorded just after the turbine is installed, and after each overhaul period. (At any future time, readings can be taken and compared with those on record.) Any difference between the readings taken at installation, or at overhauls, indicates thrust bearing wear, which should be checked as soon as possible. The normal oil clearance in the thrust bearing should be given consideration; it should not be mistaken for excessive wear.

Sometimes the rotor position micrometer is installed so that readings can be taken from the dummy piston and cylinder; it may then be referred to as a dummy micrometer.

Modern turbines are equipped with a different type of micrometer which is mounted on the forward end of the turbine shaft, with its spindle in line with the centerline of the shaft. The linear speed of any point on the shaft approaches zero as the point nears the center of the shaft. Thus, when the micrometer spindle touches the center of the shaft, it will suffer negligible wear. Therefore, in

taking one reading, instead of two, and comparing that reading with the predetermined safe limits, the axial position of the shaft can be readily determined. This type of rotor position micrometer has an additional advantage in that it does not pass through the casing of the turbine, and therefore does not require a stuffing box and packing gland.

Most modern main turbine installations are equipped with axial clearance indicators. An axial clearance in-

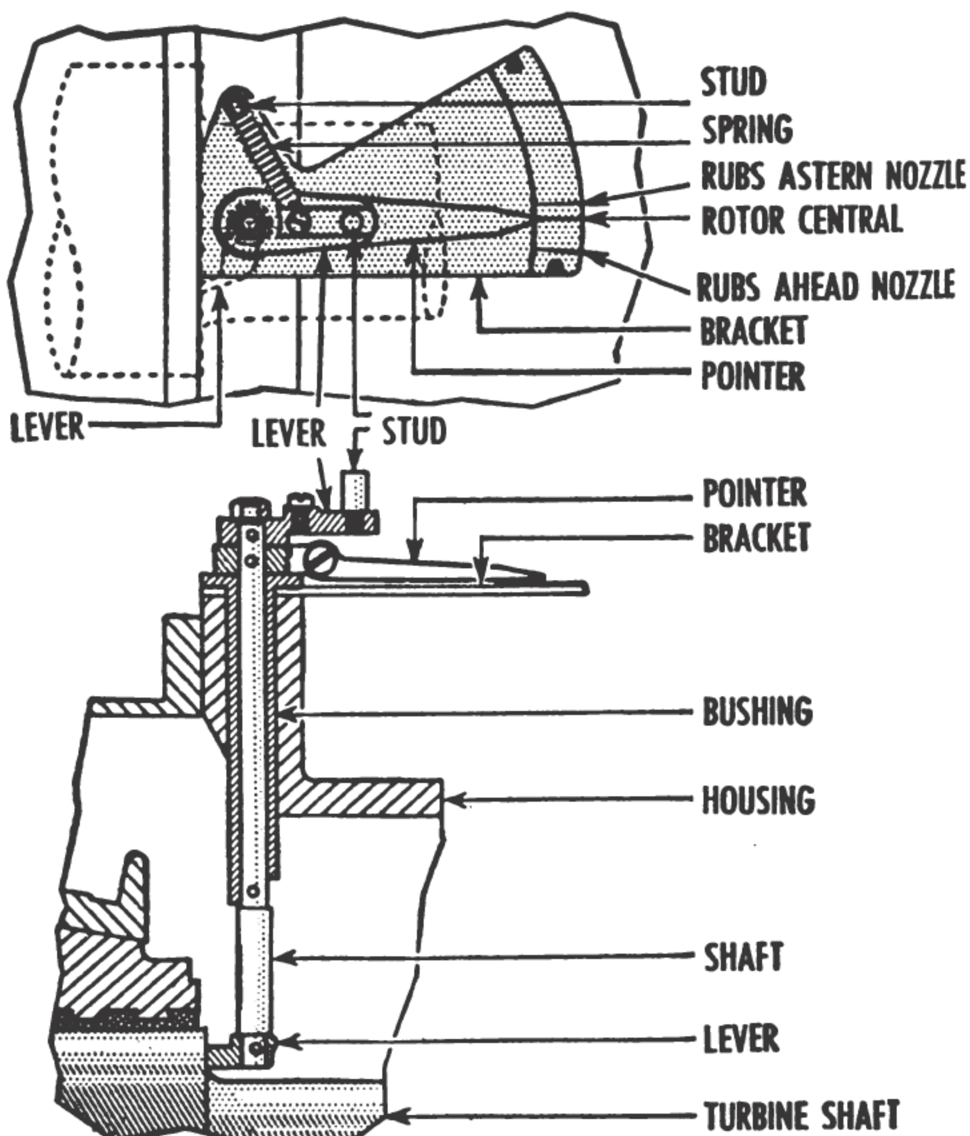


Figure 3–25.—Axial clearance indicator.

dicator of the type installed on the low-pressure turbine of a modern destroyer is shown in figure 3–25. The indicator is located at the forward end of the turbine and provides an easy means of obtaining a check on the axial position of the rotor. When not in use, the lever is held out of contact with the shoulder on the shaft by means of a spring. The indicator is used by moving the stud manually so as to bring the lever in contact with the shaft shoulder. The pointer, at its initial adjustment, indicates rotor center; and the indicator plate is marked to indicate the danger point of deviation (at which point adjustment must be made).

Maintenance of Carbon Packing Rings

The qualifications for advancement in rating require you as an MM2, to know how to fit packing rings to turbines. When carbon packing is being examined, all sections should be checked for scores, grooves, and wear in general. In addition, the springs must be carefully examined and tested. If they are found to be weak or corroded, they must be renewed.

Spare packing rings are usually provided in the ship's allowance of repair parts. The segments of a given packing ring should not be rearranged. The sequence of marking on the ends of segments should be followed. When it becomes necessary to replace or fit carbon packing rings, the detailed instructions in the manufacturer's technical manual should be followed for a particular installation.

CARE OF CARBON PACKING RINGS.—Carbon packing rings in good condition show a uniform glazed surface on the inside diameter. Scoring observed on the shaft should be carefully smoothed by the use of oil stone, with the shaft diameter being reduced as little as possible. Carbon packing rings are designed to operate without lubricants other than the natural lubricant contained in them. The presence of even the smallest amount of grease or oil in any form will prevent the rings from functioning properly. If the sealing surfaces of a packing housing become

scratched or damaged, they should be restored by the use of a very smooth oil stone moistened with kerosene. When carbon packing is inspected, as well as renewed, special care must be taken to ensure that the rings are installed in the proper grooves. Each segment, as mentioned previously, is generally marked with the groove number in which it is assembled; the groove numbers are usually stamped in the gland case. Where unvulcanized rubber dissolved in gasoline is used as gland joint compound, the gland should not be heated for an hour after assembly. However, the first time it is hot, the bolts should be tightened thoroughly. Care must be taken that none of the compound painted on the gland case joint faces is permitted to get on any of the carbon rings.

FITTING CARBON PACKING RINGS.—Accurately fitting the joints and bores of carbon packing on turbine shafts is a difficult job; it must be accomplished by hand after the original installation. A JIG AND GAGE (fig. 3–26) may be used to simplify the fitting of carbon rings and to reduce the time required to fit them. The JIG can be made from a square steel plate approximately 1½ inches larger than the inside diameter of the carbon ring. The thickness of this plate should be approximately ⅜ inch greater than the width of the ring to be fitted. The upper part of the steel plate should be turned to a diameter of 0.001 inch to 0.002 inch less than the final bore required for the carbon ring. (Depending on the installation, these diameters, as well as other figures, will differ; the figures given here apply to auxiliary steam turbine installations.) The width of the turned surface should be about ⅛ inch greater than the width of the carbon ring. The periphery of the turned surface should have marks of approximately ½ inch pitch and deep enough to raise a cutting edge, scribed in a diagonal direction; a depth of 0.003 inch is considered sufficient for these marks (fig. 3–26). At the bottom of this turned surface, add a 1/16-inch radius undercut in the adjacent surface to permit the corner of the carbon ring to bear properly on the turned surface. Cut a

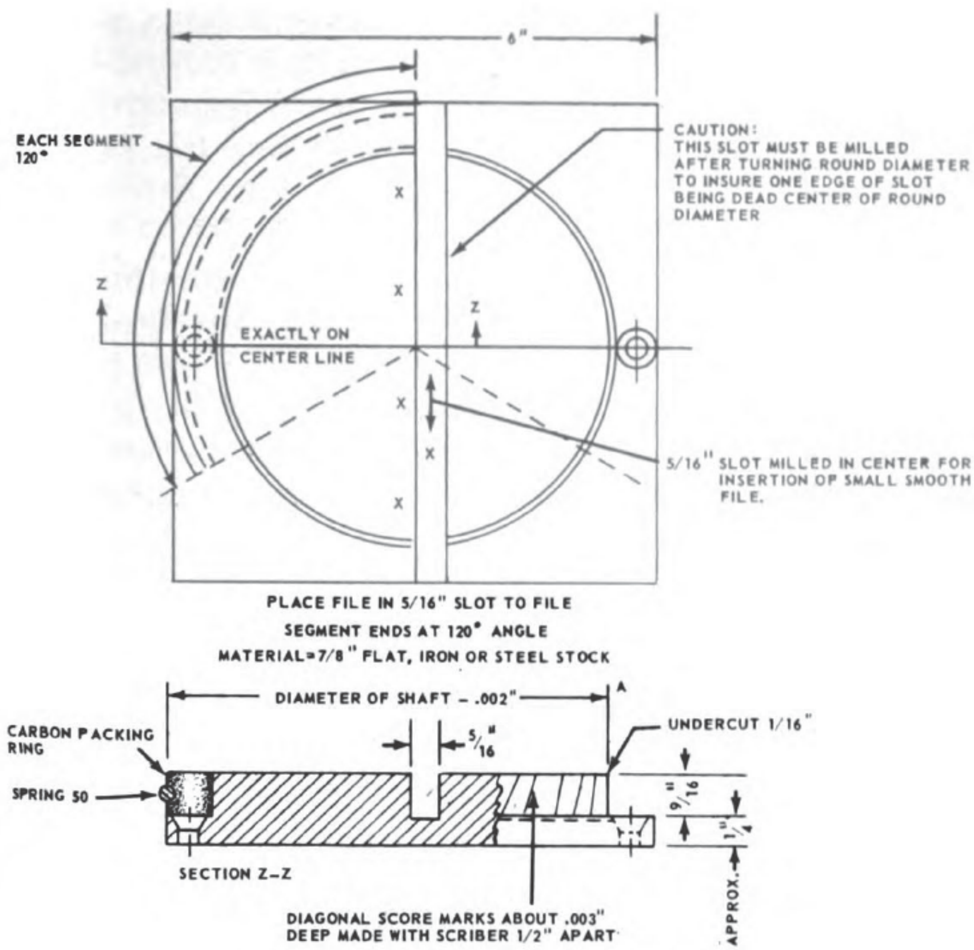


Figure 3–26.—Fitting carbon packing rings.

$\frac{5}{16}$-inch slot completely through the fitting jig to $\frac{1}{8}$ inch below the turned surface. One side of the slot must pass through the dead center of the turned surface and be true with it. Stamp an "X" on the upper face adjacent to the side of the slot through the dead center; at each end of the slot remove all sharp edges from the slot and the edge of the turned surface. Add two countersunk holes for wood screws in the portion of the steel plate which remains square, so that the jig may be fitted to a board. The heads of the wood screws should seat at least $\frac{1}{32}$ inch below the surface.

The GAGE can be made by turning a piece of steel to the same diameter as the shaft for which the carbon ring is to be used. The steel thickness should be $\frac{1}{8}$ inch greater

than the width of the ring. Drill and countersink the steel for a wood screw through the center. Both the jig and the gage can be fastened to a suitable board for convenience in handling and stowage. Both the jig and the gage can be lightened, if desired, by adding a bore through the center.

In order to FIT CARBON RINGS, assemble the individual carbon rings with its garter spring. Place the ring on the gage, and check (with feelers) the fit of joints and the clearance between the gage and the ring. If the joints do not fit properly, or if the bore is too large, remove the ring from the gage, disassemble the ring, and place each segment on the jig separately. Holding each segment securely in place, fit the joints with fine sandpaper wrapped on a flat file or a block. (The face of the slot which runs through the center of the fitting jig is used as a guide for this operation.) Remove sufficient carbon from the butts of the segments to make the assembled ring too small to go over the gage. After each joint has been refitted the entire ring is reassembled with the garter spring, and placed on the fitting jig. The ring should be held against the bottom of the jig and turned (by hand) until the cutting edges of the scribed marks have scraped out of the bore sufficiently for the joints to butt. Remove the assembled ring from the jig and try it on the gage. If it is too small, replace it on the jig and scrape it. If clearance is excessive, when checked by feelers, replace one segment at a time on the jig and remove sufficient carbon from each butt to obtain the desired clearance.

Some auxiliary steam turbines are fitted with rings which rub the shaft instead of having a clearance between the shaft and the ring, as described above. For fitting rings on these units, the jig should be made so that its diameter, after scribing and including the height of the raised cutting edges, is the same as the shaft diameter. Rings cut on this jig should make contact with the shaft along the full length of each segment. Clearances should be provided between the butting ends of the segments.

The total end clearance between the segments is usually about 0.006 inch. This clearance is provided by filing the ends of the segments as described in the preceeding paragraph.

OPERATION AND MAINTENANCE OF AIR EJECTORS

In order to qualify for advancement in rating, you must also know the purpose and principles of operation of air ejectors. However, before you proceed with this section, it will be helpful to you to review the information concerning the operation of air ejectors given in *Machinist's Mate 3,* NavPers 10522.

In most ships used by the Navy, the first and second stages of the air ejectors and their condensers have been combined into one complete assembly, as shown in figure 3–27. (In many ships, the gland exhaust condenser's functions have been incorporated within the shell of the after-condenser as shown in this figure.) The shell is rectangular in shape, and is divided by a longitudinal plate into the inter- and after-condenser sections. A baffle at the gland vapor inlet deflects the air and vapor downward over the lower bank of tubes in the after-condenser section.

In order to provide for continuous operation of the plant, two sets of nozzles and diffusers are furnished for each stage of the air ejector. Only one set is necessary for operation of the plant; the other set is maintained ready for use in case of damage to or unsatisfactory operation of the set in use. The two sets can be used simultaneously, however, when excessive air leakage into the main condenser necessitates additional pumping capacity. An inter-stage valve is provided between the discharge of each first-stage ejector and the inter-condenser so that the pressure built up by the first-stage jet, in operation, will not be lost back to the condenser, through the idle first-stage ejector. For a similar reason, a cut-out valve is located between each second-stage suction chamber and the inter-condenser. By means of diaphragm plates in the

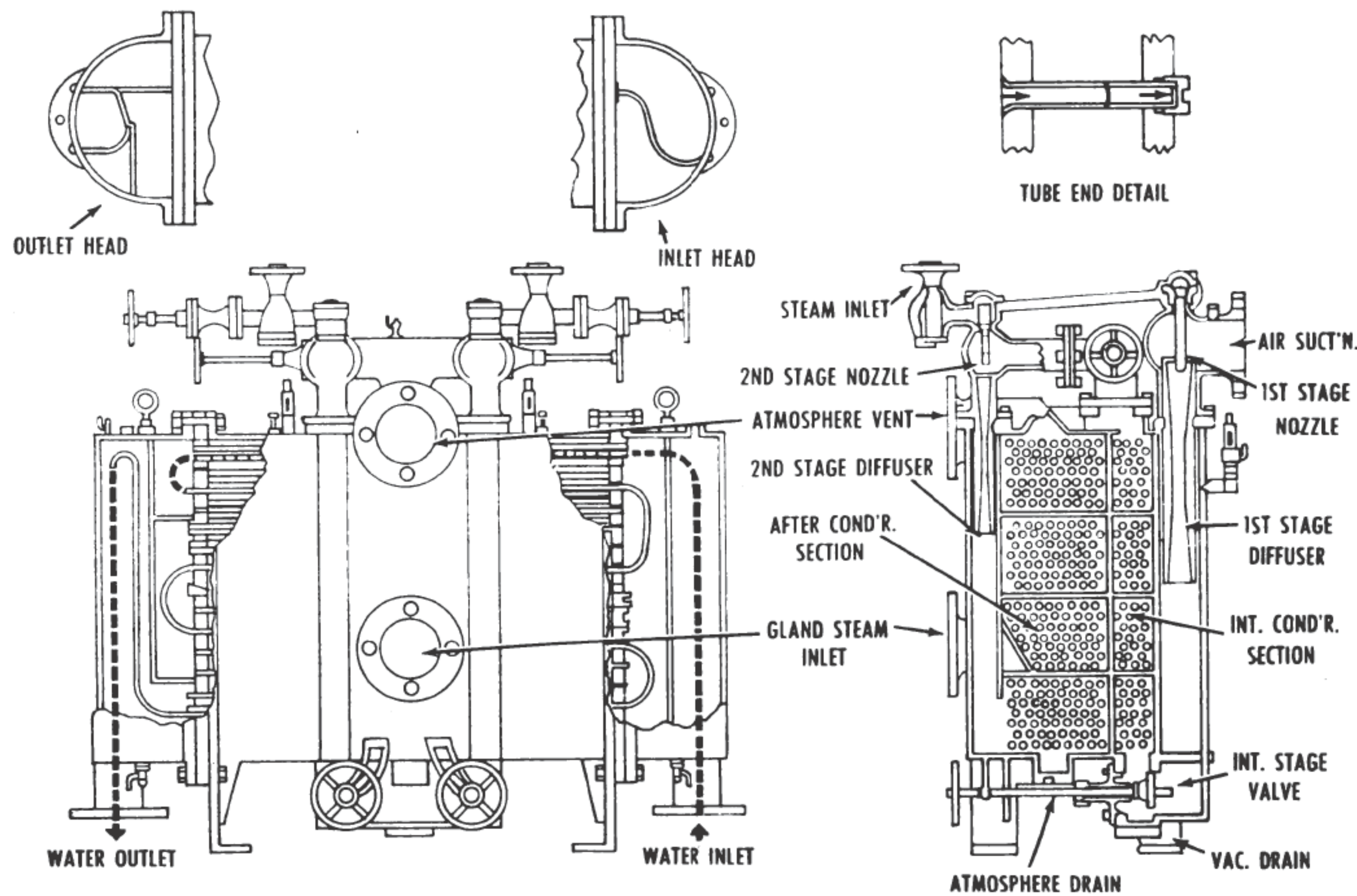


Figure 3–27.—A main air ejector and condenser assembly.

inlet and outlet heads, the cooling water (condensate) is caused to make several passes through the unit before discharging.

The atmospheric vent is usually connected to the suction of a small motor-driven fan (gland exhauster), which provides a positive discharge through piping to the atmosphere above decks. This makes it possible to avoid filling the engineroom with steam in case the air ejector cooling water supply should fail; in such a case, the jet steam is allowed to pass through the inter- and after-condensers without being condensed.

Cleaning Air Ejector Steam Strainers

The steam strainers, provided ahead of the nozzles, must be kept clean. During the first few months of operation of a newly connected unit, the steam strainers should be inspected at least once each month. Thereafter, a semiannual inspection of strainers should be sufficient, unless there is reason to believe that the strainers are not clean.

In some installations the steam pressure gages, provided to indicate the steam pressure at the ejector nozzles, are actually connected to the system at a joint ahead of the strainers. If the strainers become clogged, therefore, the air ejector may not be functioning properly because of low steam pressure at the nozzles, even though the gages indicate full steam pressure.

Draining of Steam Lines

If air ejector nozzles become eroded, deformed, or fouled, it will be impossible to operate the equipment (strainers, nozzles) under high-vacuum conditions. Erosion of nozzles is evidence that wet steam is being admitted to the air ejector, and steps should be taken to assure proper drainage of the steam supply lines. If any appreciable amount of water is contained in the motive steam, erratic operation of the air ejector will result, particularly if the water flows intermittently to the nozzle. If the strainers are not kept clean, the steam pressure

differential through the strainer is likely to rupture the strainer basket, admitting dirt or scale to the nozzle of the air ejector. In some cases, nozzles may be clogged with boiler compound, grease, or other deposits that will decrease the efficiency of the jet.

In general, it is possible to clean the nozzle thoroughly by using a wooden stick, a soft copper wire, or the reamer provided with some ejectors. These devices should be handled carefully and the proper reamer should be used for each size of nozzle, so that the nozzle will not be damaged. If it becomes necessary to remove the nozzle for cleaning or replacement, extreme care should be taken that the internal surfaces are not damaged. Dents in or other deformation of the down-stream end of the nozzle, and rough or scratched surfaces in the throat or diffuser passages, will result in improper operation of the air ejector. Any foreign deposits present on the internal surface of the nozzle or diffusers should be carefully removed with nozzle reamers or a soft copper wire.

Replacement of Parts

Before disassembly or assembly of nozzles or diffusers is undertaken, plans and manufacturers' technical manuals should be consulted. If it becomes necessary to replace a nozzle or a diffuser, gaskets of proper thickness must be used during assembly of the units. It is essential that the nozzle and the diffuser tube be concentric and in proper alignment, and that the correct distance be maintained between the ends of the nozzle and the diffuser. Remember that first- and second-stage nozzles and diffusers are not interchangeable.

It is possible to clean or to replace steam strainers, nozzles, and diffusers of an air ejector element while the remainder of the assembly is in operation. However, extreme care must be taken that the unit to be opened is first isolated from the assembly by closing the steam supply valve and the inter-stage isolating valves of this element, in order to avoid burns being suffered by personnel en-

gaged in this work. (In installations where separate inter- or after-condensers are provided for each element, isolating valves are not required.) In some installations, where a common after-condenser is provided for two second-stage elements, the internal construction of the unit is such that the steam discharged from the operating element cannot readily back up through the diffuser of the other second-stage element; isolating valves are therefore omitted from the second-stage diffuser discharges.

Dirty Condensers

Loss of vacuum and erratic operation will result if inter- or after-condenser tubes become fouled with dirt, scale, or grease. On modern ships, this condition is uncommon because condensate is employed as the cooling medium for the inter- and after-condensers.

QUIZ

1. What are the two main factors which determine whether a turbine rotor is moved by a direct impulse or by reaction to an impulse?
2. The fixed blades in a reaction turbine are similar in function to which part of an impulse turbine?
3. In what part of an impulse turbine does a pressure drop occur?
4. How do the inverted circumferential methods differ from the circumferential dovetail method of securing blades to the turbine casing and rotor?
5. With respect to the repetition of steam flow, how are turbines classified if the steam passes through the blades more than once?
6. On older types of propulsion installations, steam flow through the turbine is controlled manually by what three means?
7. How do modern propulsion control mechanisms simplify control from an operational standpoint?
8. Why are high-pressure turbines designed with relatively small blades of large pitch diameter in the first few stages?
9. How do cruising turbines differ from high-pressure turbines?

10. How are overspeed control mechanisms operated?
11. Is the ship's service generator turbine designed to operate on saturated steam, superheated steam, or both?
12. What turbine safety device will close the throttle if the turbine overspeeds as a result of failure of the speed regulating governor?
13. What is the function of the centrifugal governor of a typical ship's service generator turbine control mechanism?
14. When will the governor weights of the speed control mechanism move inward and result in an upward motion of the pilot valve?
15. When a generator turbine is being started, why should a reasonable amount of time be spent in warming up the unit?
16. What is the maximum allowable temperature of the bearings in an operating generator turbine?
17. What precaution must be taken when a turbogenerator is shut down, even for a short while?
18. How is the radial position of a turbine rotor maintained?
19. What is the major reason for maintaining a turbine rotor in its proper position?
20. If depth gages are not provided aboard ship, how often should bridge-gage readings be taken?
21. If the sealing surfaces of a carbon packing housing become scratched or damaged, what should be done?
22. How often should an air ejector steam strainer be inspected?
23. If foreign deposits are present on the internal surface of the nozzle of diffusers, what procedure should be taken?
24. What should be done before disassembly or assembly of nozzles or diffusers is undertaken?

CHAPTER 4

PUMPS, VALVES, AND PIPING

As an MM3, you have been introduced to many of the shipboard applications of pumps and valves. Detailed information concerning the purpose and principles of operation of rotary, reciprocating, and centrifugal pumps can be obtained from chapter 8 of *Machinist's Mate 3,* NavPers 10522. This chapter deals primarily with the routine maintenance and repair of pumps, valves, and piping commonly found in the various systems aboard ship.

On board ship, pumps are the most numerous units of auxiliary machinery; therefore, proper care and maintenance is an extremely important task. Operation of the ship's propulsion plant, as well as most of the auxiliary machinery, depends upon the proper operation of pumps. Faulty operation or maintenance, improper lubrication, and neglect to observe safety precautions are the major causes for pump failure. Since pump failure may result in failure of the plant or system to which the pump is providing service, you must have a knowledge of some of the operating difficulties which may be encountered; and know how to perform routine maintenance which will keep pumps in operation.

Before proceeding with this section, you should review the basic operating principles of pumps. These principles are discussed in *Fireman,* NavPers 10520–A. For additional information on pumps, you should consult BuShips *Manual,* chapter 47, and the manufacturer's technical manual which is usually furnished with each pump.

RECIPROCATING PUMPS

On modern ships, reciprocating pumps are used for two purposes in the main machinery spaces: (1) As fire and bilge pumps; and (2) as emergency or auxiliary feed pumps. Reciprocating pumps are used for emergency pur-

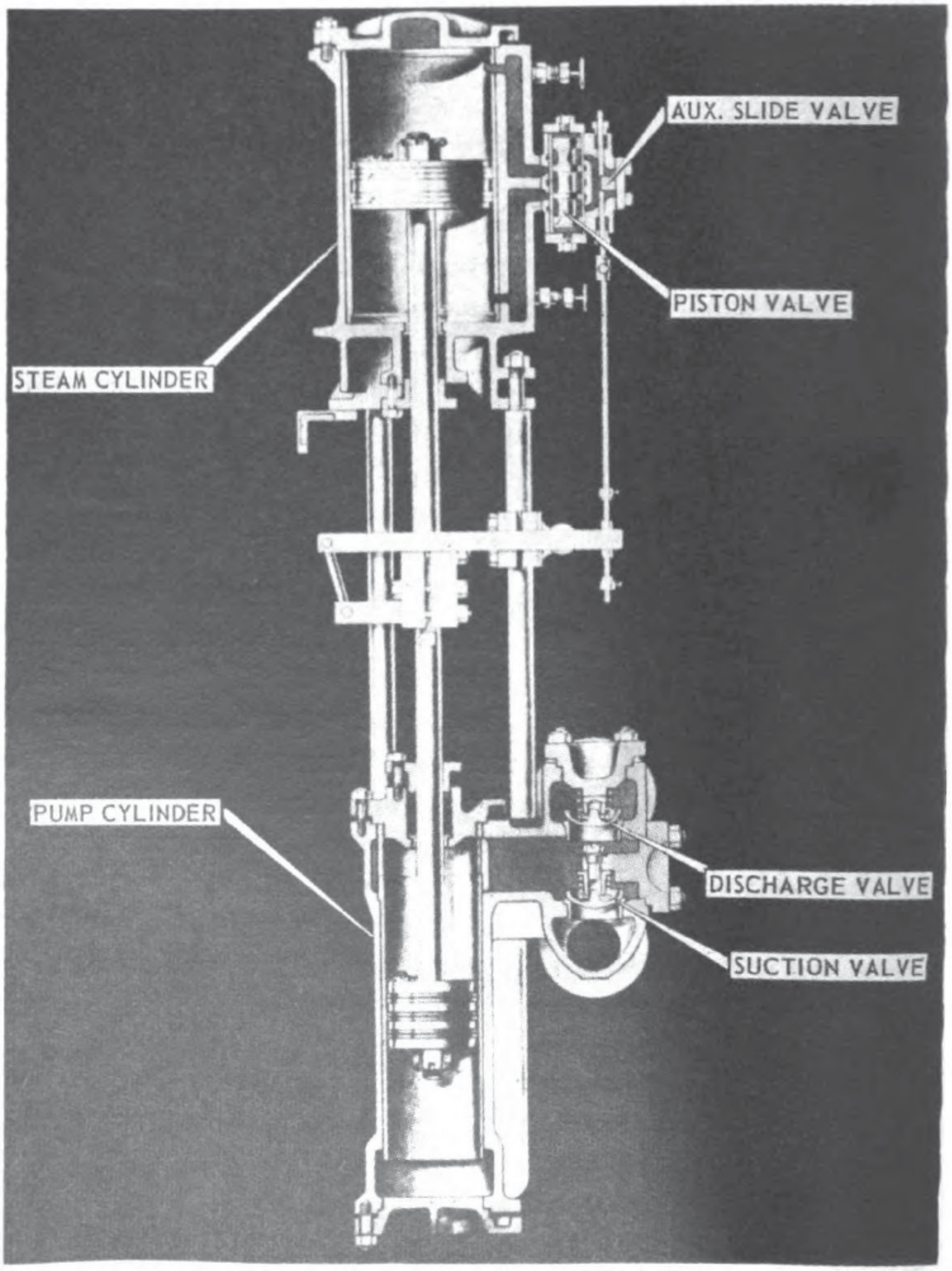


Figure 4–1.—Reciprocating pump.

poses because they are easy to operate and can be started safely by relatively inexperienced personnel. In addition, they are reliable for starting under cold conditions. The emergency or auxiliary feed pump is a direct-acting, simplex, double-acting, high-pressure, vertical pump of the type shown in figure 4–1.

Adjustment of Stroke

In order for a reciprocating pump to operate properly, the piston should travel a little beyond the top and bottom counterbore; this means that the pump must operate

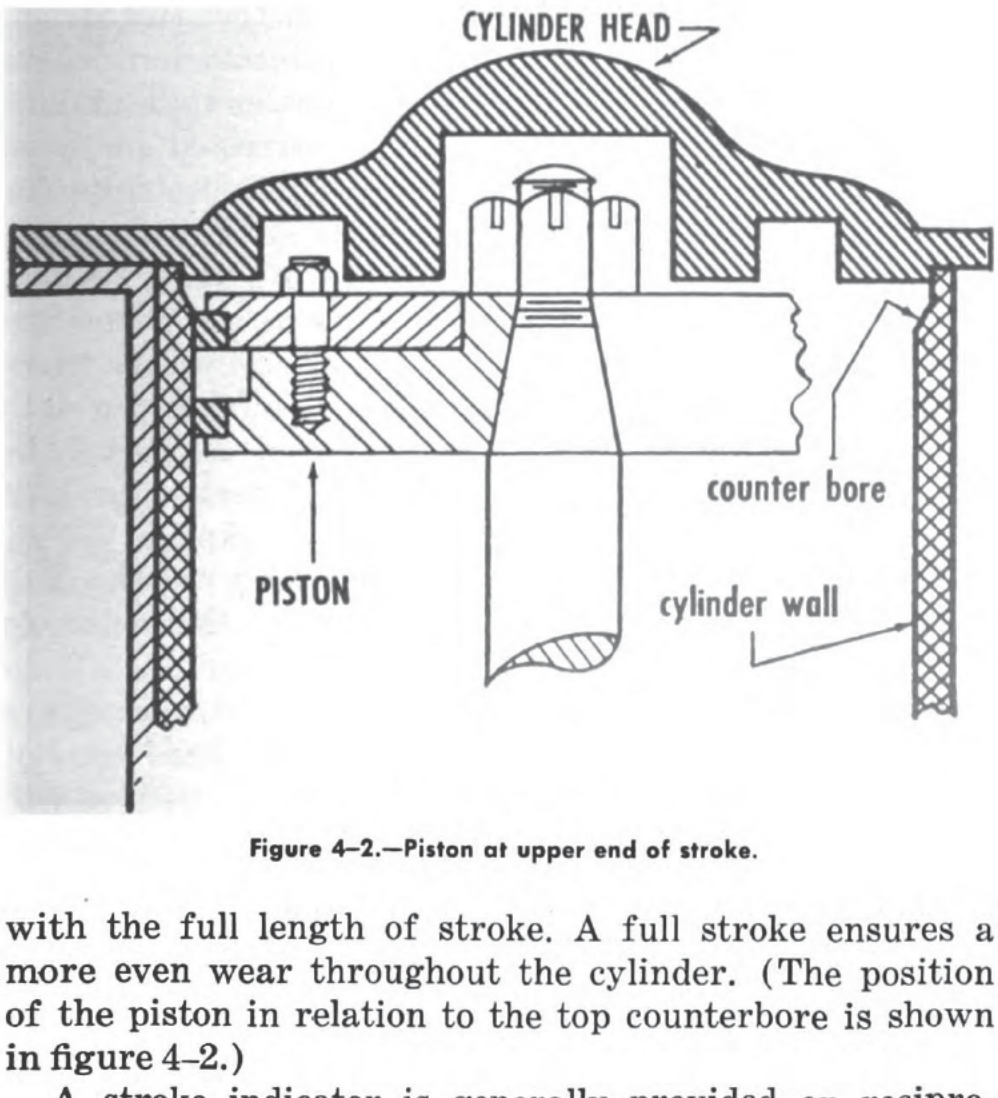


Figure 4–2.—Piston at upper end of stroke.

with the full length of stroke. A full stroke ensures a more even wear throughout the cylinder. (The position of the piston in relation to the top counterbore is shown in figure 4–2.)

A stroke indicator is generally provided on recipro-

cating pumps as an aid in checking the length of the stroke. The indicator consists of a pointer secured to the piston rod crosshead, and two marks on one of the cylinder tie rods. The upper mark should line up with the pointer on the crosshead when the piston is at the upper end of the stroke; the lower mark should line up with the pointer when the piston is at the lower end of the stroke.

When a pump does not have full stroke, something is wrong with the adjustment. Continued operation with a short stroke will cause shoulders to be worn in the cylinders with resultant breakage of rings and followers. These shoulders will have to be removed before full stroke can be obtained. Too long a stroke, or insufficient cushioning, is usually indicated by a heavy metallic knock in the steam cylinder and should be corrected at once.

Properly adjusted valves will ensure a full stroke for the various pump loads and speeds. For detailed information concerning the proper method for setting specific types of valve gear, you should refer to the manufacturer's drawings and technical manuals. However, when detailed information is not available, the following is a satisfactory method for setting steam valves. Place the piston and the auxiliary valve on the center, or on half stroke. Then move each collar from the tappet ½ the width of the steam port. If the tappet moves the full distance of the stroke, the distance from the collar to the tappet will be ½ stroke (steam port opening). Then start the pump, and, if the stroke is too short, the collars should be screwed farther apart. (If both collars are not moved equal distances from the tappets, the stroke will be longer on one end than on the other.) After the final adjustment has been made, lock the collars securely in place.

At times the steam valves of a duplex pump will have to be adjusted. Place number two piston on its top striking point, and after removing the steam chest cover of the valve chest of number one piston, adjust the slide valve

securing nuts so that there is an excess of $\frac{1}{8}$ inch full port opening to the bottom end of the cylinder. See that the upper tappet collar is bearing on the tappet. (In some cases, it may be necessary to drain the liquid end of the pump in order to jack the pistons up or down.)

To set the valve for number two piston, move number one piston to its top striking point, and follow the same procedure as above.

To test whether the adjustment is satisfactory, crack the throttle and run the pump slowly, against little or no pressure, and with the cushioning valves (if fitted) wide open. If the valves are properly adjusted, the pistons should be striking on the cylinder heads. If the pistons do not make a complete stroke after the adjustment has been made, a tight piston rod and plunger packing may be causing binding. The cause of the trouble should be determined immediately. (If cushioning valves are fitted at each end of the steam cylinder, the valves should be closed until the pump runs at full stroke, of both steam pistons, with smoothness of reversal and no striking. If it is not possible to obtain this smoothness of reversal, it may become necessary to slightly alter the adjustment of the valve operating collars.)

In figure 4–3 the piston and pilot valves are shown at the beginning of the up stroke. Both valves are in the upper position, thereby admitting high-pressure steam through the lower steam inlet port to the underside of the piston, and permitting steam above the piston to escape through the exhaust port.

When the piston reaches the top of the stroke, the lever and tappet linkage move the pilot, or auxiliary piston valve, down. This opens Port *A* to the annular exhaust space above the center of the auxiliary and main piston valves. Opening Port *A* thereby releases pressure in space *B*, below the piston valve, and permits the unbalanced higher pressure in space *C* to force the main piston valve down. The small size of the equalizing port in the piston

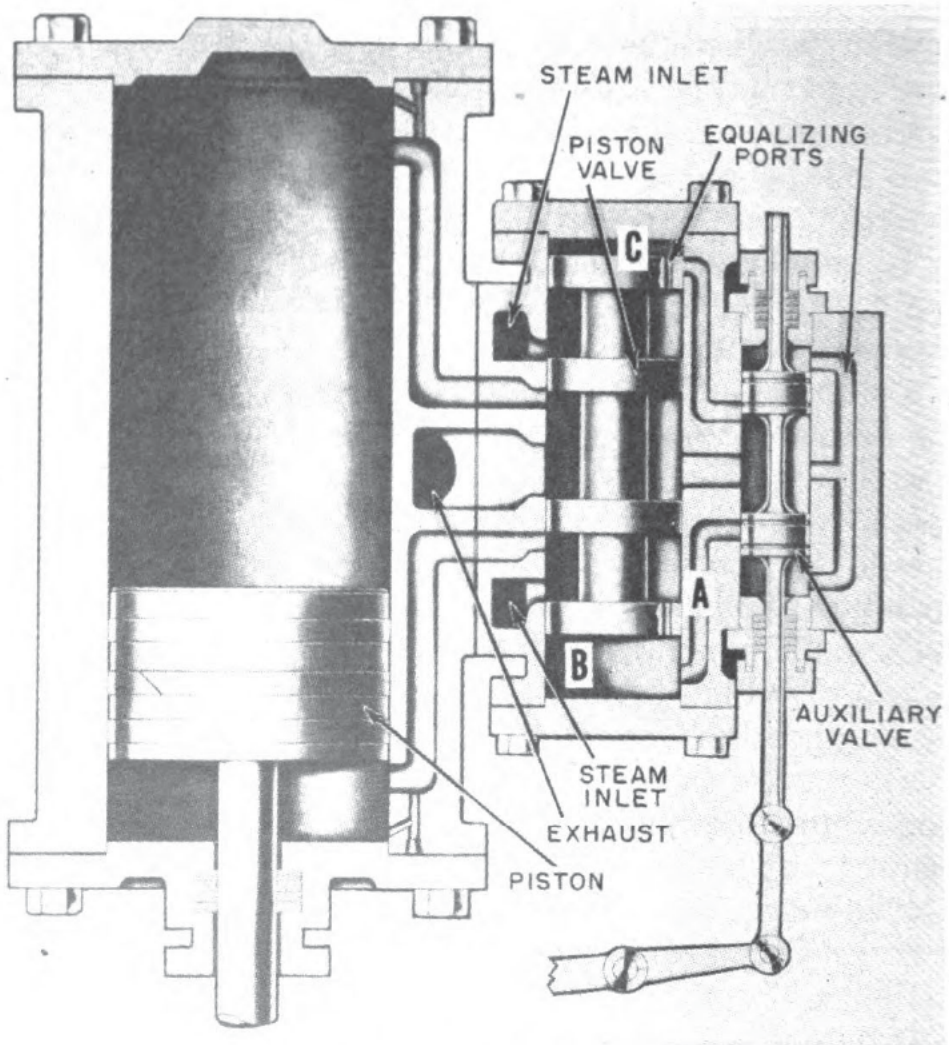


Figure 4–3.—Piston slide valve.

valve prevents the escape of any appreciable amount of high-pressure steam into space *B*. The pilot valve has blanked off the upper port, preventing the escape of high-pressure steam from space *C*—even after the downward movement of the piston valve has uncovered that port—and thereby ensuring complete movement of that valve to its lower position.

At the end of its travel, the piston valve cushions itself when it blanks off the port to space *A*, trapping dead steam which cannot rapidly escape through the small equalizing port in the valve. The initial condition of

steam balance is reestablished by means of this equalizing port. The above-described movements are repeated on the opposite end of the stroke.

The force that actuates the main valve is determined by the difference in the rate of flow of steam through Port *A*, which is 1/4 inch in diameter, and through the 1/16-inch equalizing port drilled through the outside collars of the main piston valve. Except when the main valve is actually in motion, it is in complete balance, both axially and circumferentially, so that the friction between the sliding surfaces is the only force restricting its travel. The equalizing port, which connects the outer ends of the auxiliary valve cylinder, is essential to permit free movement of this valve. As far as the actuating rod is concerned, it is generally packed lightly because only auxiliary exhaust pressures must be maintained.

Troubles and Remedies

Since there may be times when operating difficulties with reciprocating pumps will result, some of the most common causes of trouble, together with their remedies, are mentioned in this section of the chapter.

FAILURE TO START. There may be times, after you have lined up the pump and cracked open the throttle valve, that the pump won't kick over. You may proceed to open the throttle a little wider, but still nothing happens. You may repeat the starting procedure, determine that everything has been done correctly, and find that the pump doesn't operate. At this point, proceed as follows:

1. Secure the pump. Do not adjust the tappet collars.
2. Examine the discharge and exhaust lines for closed valves, or for a valve disk that has become detached from the stem. If no valves are closed, the plunger or the steam piston may be frozen, especially if the pump has been idle for some time.
3. Jack the pump with a bar to determine if there is excessive friction.

4. Disconnect the auxiliary valve stem from the operating gear, without changing the position of the tappet collars. Open the exhaust, suction, and discharge valves, then crack the throttle. Work the auxiliary valve by hand. If the packing is not seizing the stem, the valve should work freely by hand.
5. If the pump still fails to start, secure it. Remove the steam valve chest cover and examine the main piston valve to see if it has overridden or stuck.
6. If the pump cannot be started, a complete overhaul of the working parts of the steam end will probably be necessary to stop steam leakage, the most probable cause of the trouble.

FAILURE TO TAKE SUCTION. If the pump fails to take suction, the operation will be jerky. To correct this trouble, proceed as follows:

1. See that all stop and check valves in the suction line are open, and the line has no obstructions.
2. If the pump has a suction lift (as a bilge pump), it may be necessary to prime the pump before it will take suction. Salt water pumps can usually be primed from the sea by opening the sea suction valve for a short interval.

LOSS OF DISCHARGE PRESSURE. When a pump loses discharge pressure, the trouble is usually due to a leaky plunger; to a leaky, broken, or stuck valve in the water end; or to air being admitted through open or leaky valves in the suction line. Stop the pump as soon as practicable, and trace and correct the trouble. If a pump has been operating properly and loses pressure on one stroke, look for a broken valve immediately. If there is a broken valve, it should be replaced. Great loss of efficiency results from leaky suction and discharge valves, and from leaky plungers. (Previous experience with a particular type of pump may be taken as a guide in deciding where to look for the trouble. Under normal conditions, the first investigation should be made in the most troublesome areas.)

ERRATIC OPERATION. When a reciprocating pump sticks in any part of the stroke, or stops frequently (with the throttle valve opened the proper amount), the cause is in the steam end. The trouble probably results from one or more of the following defects:

1. LOST MOTION IN THE OPERATING GEAR DUE TO WEAR. This trouble should be remedied by rebushing, and, if necessary, by renewing the pin at the affected part.

2. LEAKAGE OF STEAM BY THE MAIN OR THE AUXILIARY VALVE, DUE TO WEAR OF EITHER VALVE. This trouble can be remedied by refacing the flat face of the slide valve on its seat.

3. LEAKAGE OF STEAM BY, OR STICKING OF, THE VALVE CHEST PISTON. In order to stop this, it may be necessary to rebore the valve chest cylinder, or at least renew the auxiliary piston rings.

4. EXCESSIVE LEAKAGE BY THE STEAM PISTON RINGS. In this case, it may be necessary to renew the rings, or rebore the steam cylinder, or both. Where split rings are fitted, however, the leakage can be partly stopped by removing the rings and peening them so as to increase the wall pressure. When cylinders are rebored, over-size pistons and rings should be fitted.

5. SMALL PORTS AND PASSAGES IN THE VALVE CHEST STOPPED UP WITH SCALE. This frequently occurs on new vessels because of failure to blow out all scale from the steam lines before the parts are connected.

Maintenance and Repair

Reciprocating pumps, like other equipment, require routine maintenance and occasionally, some repair work. This chapter covers some of the most important points dealing with routine maintenance and repair of reciprocating pumps. Additional information may be obtained from chapter 47 of BuShips *Manual* or manufacturers' technical manuals.

The pins of the valve-operating assembly should be kept well oiled. However, you must NOT attempt to lubri-

cate the steam or water cylinders, the valve chest or the piston rod. (A slight GLAND LEAK-OFF is all the lubrication that rods and stems require.)

Piston rod packing should be renewed whenever it becomes worn or dried out. In this case, a little routine maintenance can save a great deal of work, since it is much easier to renew packing than to replace rods.

Because of corrosion, salt-water pumps require special maintenance. Approximately every six months the internal parts of the liquid end should be examined and cleaned. If zincs are installed, they should be inspected once a month, and replaced when necessary.

Before repairing or examining a pump, assemble all the pertinent blueprints, drawings, and available data. These drawings and data will give you the required clearances, measurements, information regarding materials to be used, and other important data. In addition, you should have the complete history of the pump being repaired, so that you will know what has been done previously, when repairs were made, and what kind of trouble has been encountered with this particular pump.

Whenever reciprocating pumps are opened for repairs, micrometer or caliper measurements should be taken of the main cylinders and the valve chest cylinders. These measurements are made on the fore and aft and athwartships diameters at the top, middle, and bottom. The results should be recorded on the Machinery History Card, with an accompanying diagrammetric sketch showing the measurements obtained and the date on which they were made.

Remember that the steam end of a reciprocating pump should NOT be dismantled until a thorough check reveals that the water end is satisfactory. Most reciprocating pump troubles, however, result from fouled water cylinders, worn valves, or from faulty conditions in the pipe connections external to the pump.

SCORED WATER AND STEAM CYLINDERS. When a water cylinder becomes scored, it is not always necessary to

rebore or renew the liner. Slight scoring of the cylinder walls can be corrected by stoning. A water cylinder should not be rebored unless it is worn out of round, or has tapered beyond the maximum allowable amount, as tabulated in table B–5 of chapter 40 of BuShips *Manual.*

Scoring in a steam cylinder, even though of a minor nature, necessitates reboring to prevent steam leakage past the piston. The presence of such leakage is indicated by a dullness and discoloration of the cylinder walls. Once leakage has started, steam will gradually cut away cylinder walls until leakage past the piston becomes so excessive that it interferes with the proper operation of the pump.

LOOSE PISTONS. Pistons at the water end of pumps are generally constructed of cast iron and are of the body and follower type. The piston itself is not a tight fit, but depends upon several rings of fibrous packing to prevent leakage. These rings of packing are placed between a shoulder at one end of the piston and a follower plate at the other end. A water piston is shown in figure 4–4.

If a steam or water piston works loose on the rod, it is generally due to poor workmanship and assembly, or to the rod being so fitted that the shoulder bears against

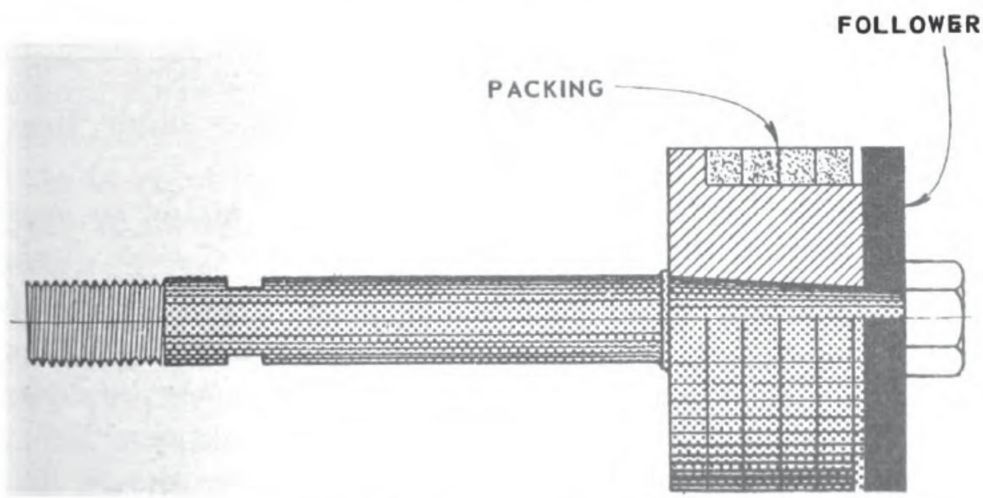


Figure 4–4.—Liquid plunger and piston rod.

the piston without giving a proper bearing surface for the tapered part of the rod. When set up handtight, the piston should fit within $\frac{1}{32}$ to $\frac{1}{8}$ of an inch of the shoulder; it should then be forced tightly against the shoulder by the securing nut. However, the piston cannot be brought firmly home unless all foreign matter has been removed from the taper of the rod. Piston trouble will usually disappear when the piston is properly refitted to the rod. (If a jamb nut or a split pin is not fitted, one should be installed.)

PISTON TOO SMALL. Pistons may be built up by flowing on metal by the oxyacetylene method, by electric welding, or by metal spray. The piston is then machined to the proper fit.

It sometimes happens that in reboring a water cylinder you introduce so much clearance that the piston and the follower require renewal. Until a new piston and follower can be obtained, one of the following procedures may be used:

1. The piston and the follower may be built up by flowing on metal, then turned to the correct diameter.
2. The piston and the follower may be turned down and threaded, and threaded rings screwed on tightly. Then machine the outside diameters of the rings to fit the cylinder.

TESTING TIGHTNESS OF STEAM PISTON IN CYLINDER. To test the tightness of the steam piston in the cylinder, proceed as follows:

1. Remove the cylinder head. Shore the piston to prevent forward or upward motion.
2. Connect a steam hose to the lower drain cock and gradually raise the pressure to the working pressure of the pump or the hose, whichever is less. If the rings are not tight, steam will leak past them. It must be remembered that this test shows defects for only that portion of the cylinder occupied

by the piston. If measurements show that there is a great difference in size in various parts of the cylinder, the test should be repeated several times. During each test, the piston should be in a different part of the cylinder.

BREAKING OF FOLLOWERS. The breaking of followers and bolts may result from misalignment. This trouble may also result from screwed plugs in the piston working loose and coming adrift. When a piston is to be examined or repaired, make certain that the plugs are tight. The plugs should be prick-punched to prevent their backing out.

However, when such trouble occurs in any one set of pumps on board ship, it may result from a weak follower. In this case, the Bureau of Ships should be notified so that the design may be improved and alterations authorized. (A new and heavier follower, or one of better material, can be tried on a pump to see if it stops the trouble. The breaking of followers can be prevented by drilling the piston for through bolts for securing the follower.)

When the follower is too small in diameter, plunger packing will frequently roll up between the piston and the cylinder, causing the follower to jam and break.

RENEWING PLUNGER PACKING. Tuck's, flax, or other types of soft packing should be soaked in hot water for at least 12 hours before it is fitted and installed in a pump. In emergencies, however, when there is no time for soaking, the packing may be used without soaking if it is cut with enough clearance to allow for swelling. Failure to do this will cause the pump to groan, or may result in a scored cylinder.

WORN OR BROKEN PISTON RINGS. Troubles in the steam cylinder result chiefly from faulty piston rings. Wearing of piston rings can cause a pump to lose power, and even, in some cases, to stop. If a pump stops, while operating slowly, in the middle of a stroke, the trouble may be due to worn rings. In this case, secure the pump and ex-

amine the condition of the rings and the cylinder. If necessary, renew the piston rings.

Figure 4–5 shows a steam piston assembly of a reciprocating pump. The piston rings are cast iron. If the piston rings are broken or worn or have been poorly fitted so that there is excessive leakage by the piston, new rings must be installed.

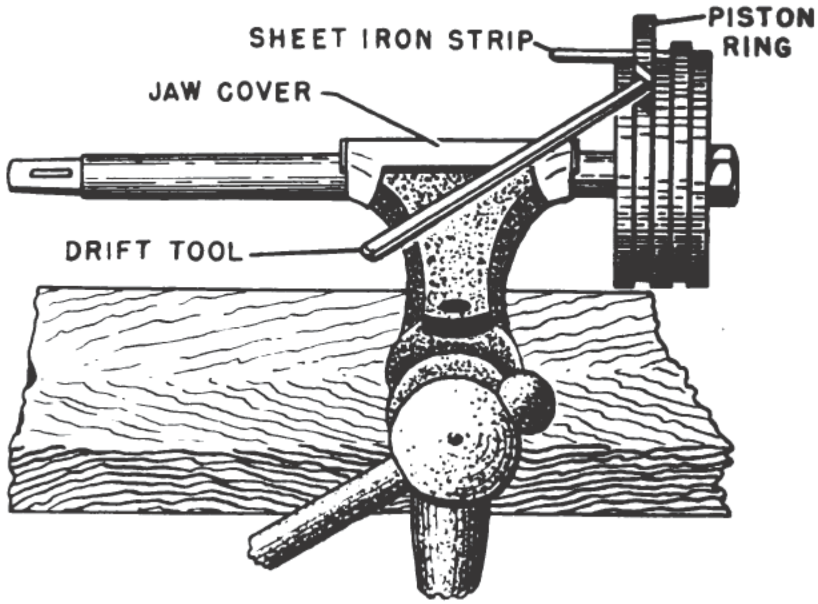


Figure 4–5.—Removing piston rings.

To remove a piston ring, hold the piston rod and piston in a vise, as illustrated in figure 4–5. (When doing this, use soft metal covers on the vise jaws to prevent digging into or otherwise abrading the polished surface of the piston rod.) Pry the end of the old ring by means of a thin, pointed drift tool and a strip of sheet iron or an old piece of hacksaw blade, as shown. Continue the prying and add more strips until the ring is raised out of its groove and can be slipped off the piston. (Rings of built-up pistons, however, can be removed by removing the follower plate studs and disassembling the piston.)

When the rings have been removed, take micrometer measurements of the cylinder or liner, to determine the exact diameter. In addition, measure the width of the

ring grooves in the piston to determine the width of the new rings. The inside diameter of the new ring can be determined by checking the applicable blueprint or by obtaining it from one of the old rings. If you do the latter, place a piece of chart paper in the gap where the ring is cut, bind the ring so that the ends butt up snugly, and then measure the inside diameter.

When replacing piston rings, first fit the new rings to the cylinder to check the GAP clearance. If the gap

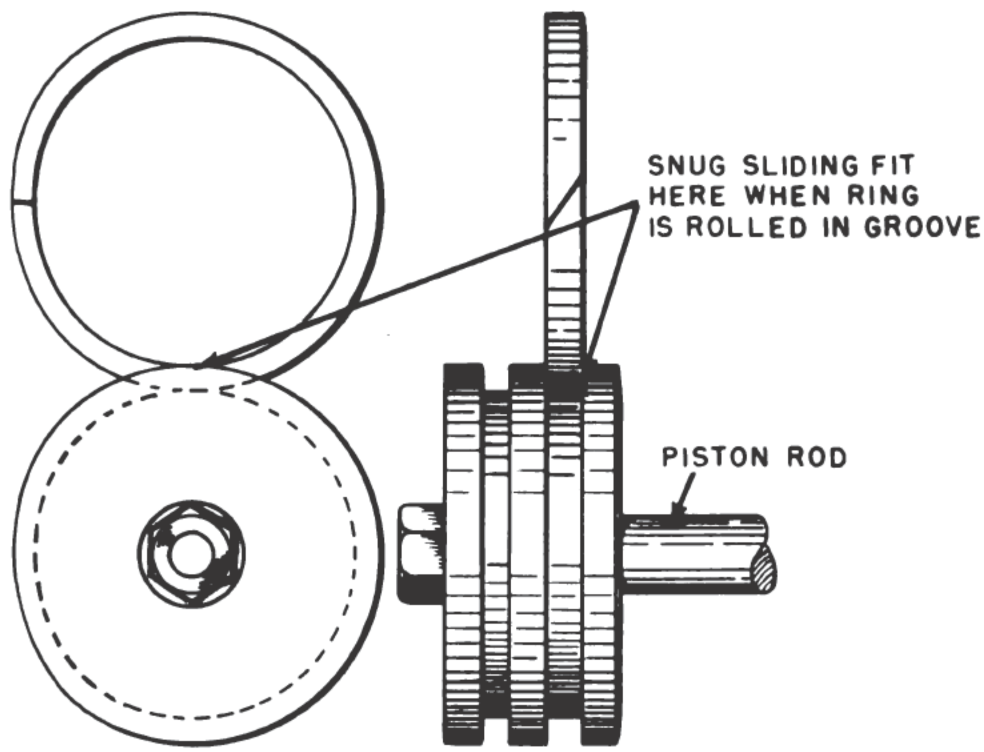


Figure 4–6.—Fitting piston rings.

clearance is not specified on the blueprint, allow a clearance slightly less than 0.001 of an inch per inch of cylinder diameter. For example, a clearance of 0.007 to 0.008 inch should be allowed for a piston ring of a 10-inch cylinder. If necessary, file the ends until proper clearance is obtained. The width of the rings should be checked, to make sure that they will fit into the grooves properly. If no clearance data is available, you can fit the piston

rings by rolling them around the grooves. The rings should fit snugly, yet roll freely (fig. 4–6). If they do not roll freely, polish the sides of the rings lightly on fine emery cloth held against a smooth and even surface. Repeat the process until the rings fit properly in their respective grooves. (The ring gaps must be staggered so that they do not fall in one line.)

VALVES IN WATER END. All valves in the water end of the pump must be kept tight to ensure satisfactory and economical pump operation. Cast valves may be faced off in a lathe and then ground in on their seats by a simple device consisting of a length of rod slotted to fit a piece of metal which seats across the top of the valve. An ordinary bitstock can be used to do the grinding.

It is sometimes desirable to take a cut off the valve seat without removing it. A simple cutter can be made with an extension for a bitstock similar to the grinding-in device. When flat valves are fitted, the seats may be trued up by using a small surface plate and spotting in the section on the surface plate.

After the valves have been ground in, test the entire pump by closing the discharge valve, starting the pump, and checking the proper suction and discharge pressure.

At each examination, try all metal valve disks with a straightedge to see if they are true, and test the spring tension of the valves. Tension on the valve springs should be great enough to ensure a quick closing of the valve, but not so great that the valve cannot be lifted easily by hand. See that the springs are tightly secured by split pins, and adjust the valves to give the proper fit. The lift should be such that the circumferential opening is slightly greater than the clear opening through the seat, but NOT greater than one-quarter of the diameter of the opening.

Keep the valves clean; a light mineral oil makes a good cleanser, and a lye or soda solution is satisfactory for removing caked or gummed oil from the valves.

In pumps having valve seats secured only by a taper fit, the seats should be forced home by a jack resting on the end of a reseater which, in turn, rests on the face of the valve seat. If the seat works loose, peen the edge of the metal slightly. In pumps that have the valve seats screwed into the pump diaphragm, always insert the valve seats with white lead; otherwise it will be practically impossible to get them out.

In some pumps, the discharge valve seats in the water end are secured to the pump diaphragm by shoulders on the valve stems where they screw into the suction seats. These seats have small flanges under which gaskets are fitted. Rubber gaskets supplied by the manufacturer are soon squeezed out, causing the seats to leak and hammer. Hard sheet packing will give better performance than rubber, and if cold water is to be pumped, sheet lead will give the best performance. In cases where the flanges cause a great deal of trouble, it will be necessary to fit new seats with a ground joint.

Extreme care should be exercised in assembling pumps after overhaul. Mark valves, seats, stems, and springs before removal, so that you will be able to match them in sets for proper assembly.

CARE OF STEAM VALVE MECHANISM. The same care must be exercised in fitting the valve chest steam cylinder, cylinder rings, and piston as is used in fitting the steam piston and cylinder. It is most important that all wear be kept out of the steam valve operating mechanism. Failure to do this will cause the pump to operate in a faulty manner, and perhaps to stick. The pins should be rebushed and renewed as often as necessary. If wear of bushings occurs rapidly, despite careful lubrication, the holes may be bushed with tool steel bushings.

All steam valves must be kept tight because, if the auxiliary valve leaks, the main valve will become steam bound; that is, the steam pressures in the various passages and parts of the auxiliary valve chest and the main valve chest cylinders will equalize, and the pump

will stop. Flat steam valves should be kept true by scraping, and the piston rings of piston valves kept free in the grooves. When scraping flat steam slide valves, the strokes of the scraper should cross, so that the scraper will not chatter on the narrow bridges between the ports, and result in steam leakage when the valve is in operation.

As a result of frequent spotting in of the main and auxiliary valves, the relative size and arrangement of port openings may change owing to irregular coring. A simple method used to check the accuracy of the valve action is to cut paper patterns of the valve and the valve seat faces by laying the paper on the valve and peening with a hammer. Sliding the pattern of the valve over that of the seat will show the exact laps, leads, and port openings, which can be checked with the drawings.

REPAIRS TO VALVE CHESTS, LINERS, AND PISTON RINGS. Preventive maintenance of steam valve chests operating under high steam pressures is most important to avoid serious steam cutting and wear. Careful attention to lapping out these early cuts will ensure a tight metal-to-metal fit of the valve chest and steam cylinder.

Attention to the condition of piston rings on the main and auxiliary valve, with timely replacement, will preclude broken rings and steam cutting in the grooves.

Prior to making up the metal-to-metal joint, it should be blued and tested for good over-all contact. If the joint is not a good metal-to-metal fit, or if scores or leakage are evident, remove the studs from the steam cylinder and lap the steam chest in against the cylinder seat.

In making up the joint, strict cleanliness must be observed so that no particles of dirt or scale will prevent a good metal-to-metal contact of the ground faces. A thin film of copaltite should be applied. The holding-down bolts should be taken up gradually and alternately in a diagonal sequence. After steam is applied and the pump is in operation, the holding-down bolts should be taken up again.

Do not install gaskets on the steam chest joint. Such a

gasket tends to blow out around the steam passage lands, thus aggravating the cutting action of the steam.

When continued lapping of the valve chest and the steam cylinder surfaces have worn them down to the extent that they must be built up to the original dimensions, then both should be overlayed and brought back to the design dimension. When piston valve chest joints, lands, and other parts are badly damaged by wear and steam cutting, the repair procedures given below in the following paragraphs are authorized by the Bureau of Ships. (Refer to figure 4–7 for identification of the areas to be repaired.)

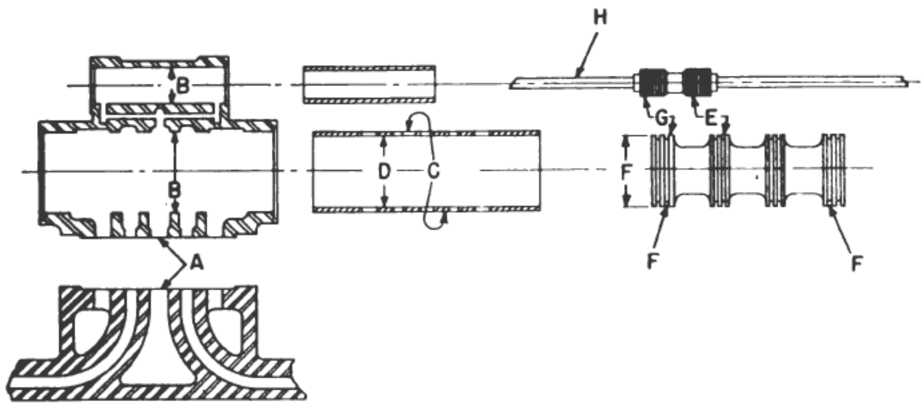


Figure 4–7.—Repair of valve chests, liners, and piston valves.

Joint face *A* (fig. 4–7), between the steam chest and the cylinder, may be built up by overlaying with one of the following electrodes in accordance with Specification MIL–R–17131, grades MIL–R–11A1–40, MIL–R–VD2–50, or MIL–R–II–C1–40. Both surfaces should be brought back to their design dimensions.

Main liner chest lands *B* may be built up with 25 percent chrome, 20 percent nickel corrosion-resisting steel welding electrode.

Liners should be replaced, if possible, rather than subjected to extensive repair. However, if spare liners are not available, the individual liner may be chrome plated on the outside area *C*. In such cases, liners should be

shrunk into place. Pressing chrome-plated liners into the chest will result in galling. Chrome plating of the inside or wearing surface of liners (area *D* of fig. 4–7) is not authorized; such a repair would do away with the graphitic lubrication provided by the original special alloy iron liners.

Main and auxiliary valves should be replaced when worn or steam cut. Building up ring grooves *E* with chromium cobalt composition (MIL–R–II–A1–40) is authorized, if replacement valves cannot be obtained. The original valve material has a hardness of approximately 200 Brinell; the liner, approximately 500 Brinell. Thus, wear will be taken on the pistons rather than on the more expensive liners. Therefore, overlaying of the ring grooves with a harder material than the liner should be avoided, to prevent rapid wear of the liner.

The end lands of main piston valves may be found to have insufficient clearance with the liner. The clearance on diameter between end lands *F* and the liner should range from 0.002 to 0.0025 inches per inch of diameter. Center lands should have approximately half of this clearance.

Replacement piston rings *G* should be of cast iron (as originally installed) in order to obtain the required finish on the working faces.

If tail rods *H* are to be replaced, they should be of *K* monel metal in order to avoid corrosion and the danger of rust working loose in the valve chest. Chrome plating of the original carbon steel rods is satisfactory as a repair.

Tests for Reciprocating Pumps

The following tests should be conducted on reciprocating pumps:

1. Jack over all idle pumps by hand DAILY.
2. Move all pumps by steam or power WEEKLY.
3. Inspect liquid end valves, valve stems, and springs; inspect steam valve gear for wear; and check setting of relief valves QUARTERLY.

Safety Precautions

The following safety precautions should be observed when operating and maintaining reciprocating pumps:

1. Never try to jack over a pump while the steam valve to the pump is open.
2. Before opening a steam cylinder or steam valve gear, see that the drains are open, and that the steam and exhaust root valves are wired closed.
3. Before opening the water cylinder or the valve chest of a pump handling water at a temperature in excess of 120° F., make certain that the suction and discharge valves are wired closed, and that the cylinder and the valve chest are drained.
4. Always open the steam cylinder drain valves when the pump is shut down, and leave them open until the pump is again in operation and has been cleared of condensate.

ROTARY PUMPS

Positive displacement rotary pumps have largely replaced reciprocating pumps for pumping viscous liquids in naval vessels, as they have a greater capacity per weight and occupy less space. (Positive displacement means that a definite quantity of liquid is pushed out on each revolution.) Rotary pumps are also used for pumping nonviscous liquids, such as water and gasoline, where the pumping problem involves priming or a high suction lift.

Operation of a positive-displacement or rotary pump depends upon the principle that rotating screws, lobes, or gears trap the liquid in the suction side of the pump casing and force it to the discharge side. In such pump systems it is essential that all clearances between rotating parts, and between rotating and stationary parts, be kept to a minimum, in order to reduce slippage (leakage) from the discharge side back to the suction side. With close clearances, it is necessary to operate the pumps at

a relatively low speed to maintain these close clearances; otherwise erosive action would soon cause excessive wear and increased clearances.

Types of Rotary Pumps

As you know, there are several types of positive-displacement rotary pumps, including the simple-gear, herringbone-gear, helical-gear, lobe, screw, rotary-plunger, and moving-vane types. Since the latter two types were not discussed in *Machinist's Mate 3,* NavPers 10522, they will be discussed in this chapter. (Information concerning the other types of rotary pumps can be obtained from either chapter 8 of *Machinist's Mate 3,* NavPers 10522, or the appropriate manufacturer's technical manual.)

ROTATING-PLUNGER PUMPS. These types of pumps are used in the naval service for the following applications: fuel oil and Diesel oil service, fuel oil booster and transfer service, fuel oil tank drains, lubricating oil service, and Diesel oil service.

Figure 4–8 illustrates the main operating parts of the rotating plunger pump (sometimes classified as a "cam-and-plunger" pump). The plunger is shown in three positions, (1) to (3), illustrating the pumping process. The main body of the pump is a cylinder with the suction port entering through the side, as shown, in the upper left-hand corner. The drive shaft, concentric with the pump cylinder, carries an eccentric strap which has a slightly smaller diameter than the pump cylinder. This eccentric strap operates as a piston or "plunger." The eccentric arm plus the radius of the plunger is equivalent to the radius of the cylinder less the necessary operating clearances. Therefore, with each revolution of the eccentric, the point of nearest contact of the plunger on the cylinder wall rotates completely around the cylinder. Motion of the plunger about its own center is constrained by a hollow arm, or slide, which extends from

the plunger through a slot in the top of the cylinder, and above that point, through a slotted pin carried in a bearing which seals the cylinder space from the discharge space.

Referring to (1) in figure 4–8, it may be seen that liquid trapped in the right side of the cylinder will be forced through the hollow arm to the discharge line as the eccentric rotates counterclockwise. View (2) shows the next phase with the space on the left side opening, thereby creating a vacuum which causes liquid to flow in from the suction line. The next stage, shown at (3), illustrates the discharge port, at the bottom of the hollow arm, beginning to close. The discharge port is closed by the slide pin, during the suction portion of the stroke.

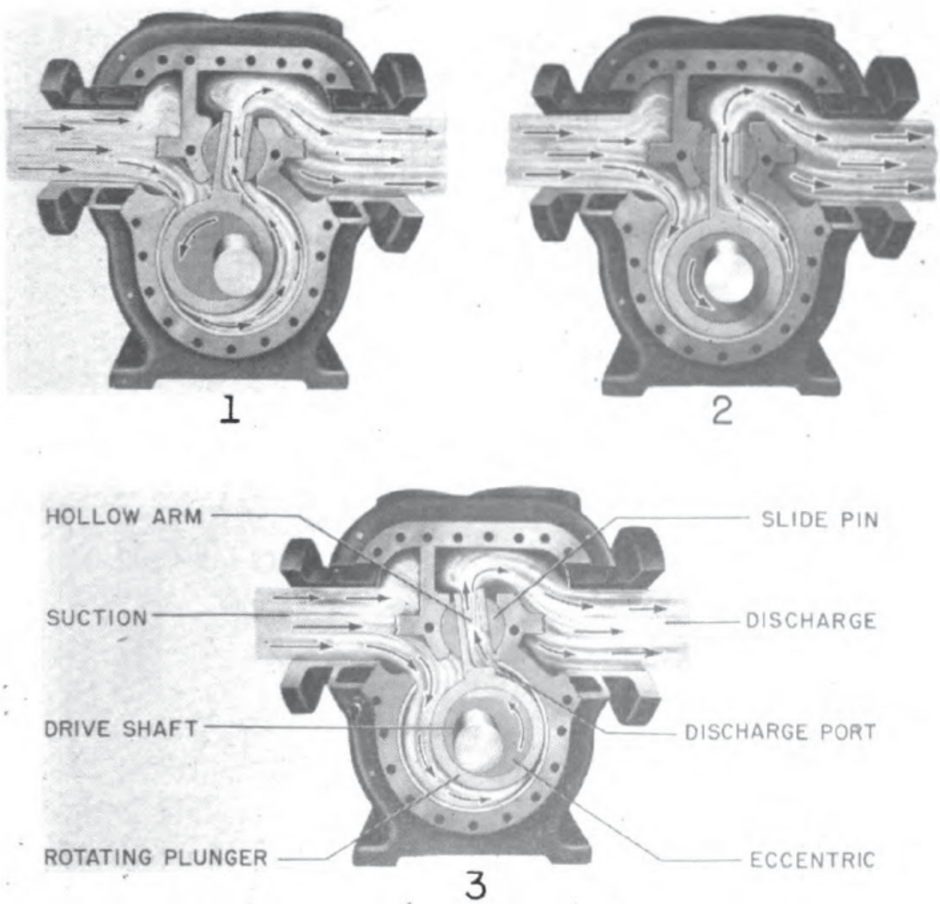


Figure 4–8.—Operating parts of the rotating-plunger pump.

When the eccentric turns slightly further, the point of contact of the plunger on the cylinder will pass over the suction port and trap the new charge on the discharge side, as shown in view (1).

In order to reduce the tendency to pulsate, rotating-plunger pumps usually employ two plungers whose driving eccentrics are 180° apart on the shaft. The plungers are separated by a diaphragm through which the shaft extends.

MOVING-VANE PUMPS. The moving-vane type pump, illustrated in figure 4–9, consists of a cylindrically bored housing with a suction inlet on one side, and a discharge outlet on the other side. A cylindrically shaped rotor of less diameter than the cylinder is driven about an axis

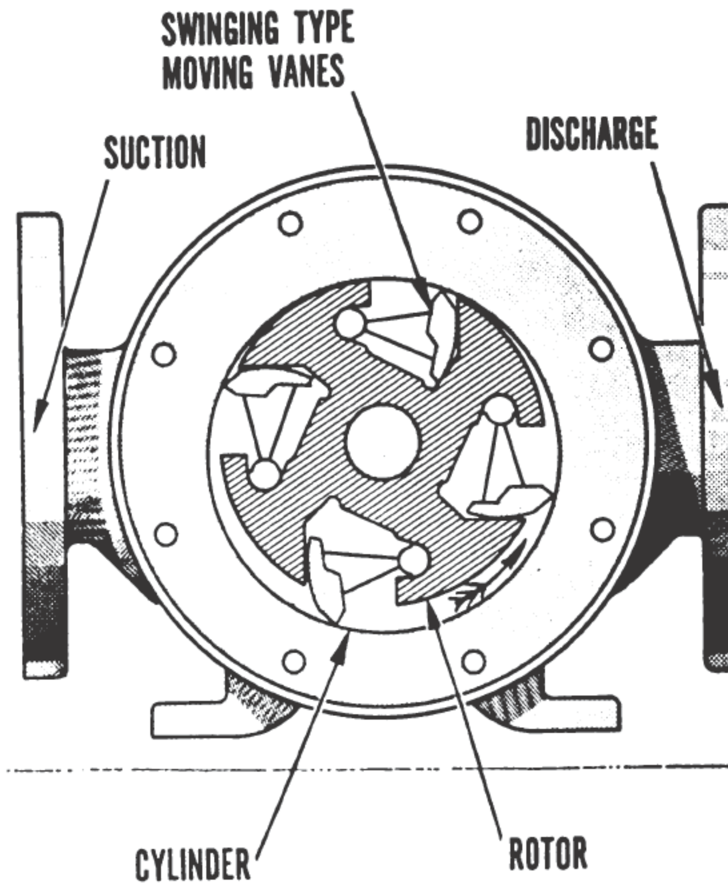


Figure 4–9.—Moving-vane type pump.

placed above the center line of the cylinder so that clearance between the rotor and cylinder, at the top, is small, and is at a maximum at the bottom.

The rotor carries vanes which move in and out as it rotates to maintain sealed spaces between the rotor and the cylinder wall. The vanes trap liquid on the suction side and carry it to the discharge side where contraction of the space expels liquid through the discharge line. The vanes may swing on pivots, as shown in the illustration, or they may slide in slots in the rotor. This type of pump, as well as other vane-type pumps, is used for lubricating oil service and transfer, and in general for handling lighter viscous liquids.

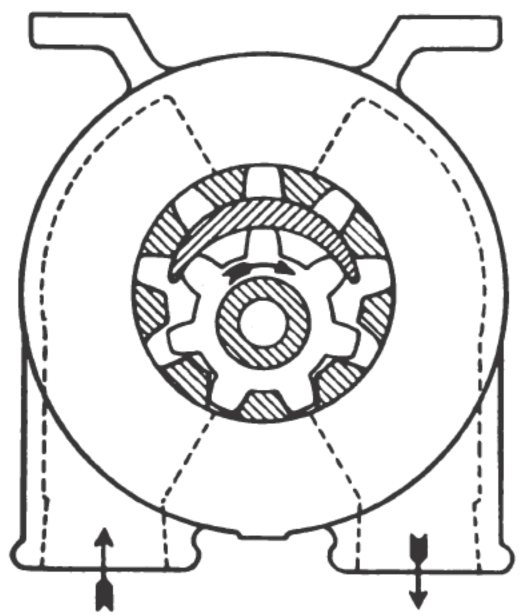


Figure 4–10.—Internal-gear type pump.

INTERNAL-GEAR PUMPS. In most Diesel installations, internal-gear pumps are used as fuel pumps, lubricating-oil pumps, and as sea water circulating pumps for cooling systems of small high-speed engines and of some medium-sized engines. Figure 4–10 illustrates an internal-gear type pump which is generally used for Diesel oil services.

Maintenance and Repair of Rotary Pumps

The instructions given in this chapter for the maintenance and repair of rotary pumps are general for all makes and types. For all individual pump installations, except some small miscellaneous motor-driven pumps, manufacturers' technical manuals are furnished with plans. These manuals should be studied carefully before attempting to operate or service an individual pump.

WEARING PLATES AND LINERS. Clearance between pump rotors and casing wearing plates and cylinder liners should be maintained in accordance with the manufacturer's plans. On low-pressure low-suction lift pumps, such as lubricating-oil pumps, and tank drain pumps, the pressure drop across the clearance spaces does not generally exceed 50 psi. With these types of pumps, the clearance between parts may wear as much as 0.005 to 0.010 inch without appreciable effect upon the capacity of the individual pump. However, when the clearances are excessive, renewal of parts (wearing plates and liners) will be necessary. If, in the case of fuel oil tank drain pumps, the pump will pull a vacuum of at least 16 inches mercury, with the suction valve closed, renewal of parts will also be necessary. In each case (where renewal may be required), the engineering officer should decide whether or not the amount of wear or increased clearance necessitates renewal of parts.

If the pump bearings are worn excessively and it becomes necessary to renew the bearings, do not install the new bearings without spotting them in, or checking and fitting them to the designed clearance. (A description of how to fit bearings is given in the section dealing with centrifugal pumps.) The required oil clearance for bearings is usually given on the manufacturer's plans. If these plans are not available, refer to the table of tolerances and clearances in chapter 40 of BuShips *Manual.*

TIMING GEARS. Pumps fitted with timing gears must have the correct clearance between the two pumping

rotors during operation. To accomplish this, the gears must be securely locked to the rotor shafts in their exact designed position. Be sure that there is no lost motion caused by the looseness of keys or pins holding the rotors on the shafts.

THRUST BEARINGS. The importance of the proper setting of thrust bearings, which hold the pumping elements centrally in the pump casing, cannot be overstressed. Thrust bearings should be examined quarterly and the position of the rotors checked. When the rotor position is being checked, sufficient allowance should be made for expansion of the shaft from the cold condition to the hot running condition.

COUPLINGS. When the driving unit is connected to the pump by means of a flexible coupling, remember that the coupling is intended to take care of but slight misalignment. Where misalignment is small the coupling should operate satisfactorily without requiring frequent renewal of parts (coupling). However, if misalignment is excessive, the coupling parts are subjected to severe punishment, necessitating frequent renewal of pins, bushings, and bearings.

Couplings with self-contained oil have been used for a number of years and, if kept lubricated, proved satisfactory. However, some couplings may become defective because oil has been lost, or no oil has been added, resulting in wear and breakage of teeth. Therefore, the following precautions should be observed:

1. Inspect the flexible coupling monthly by removing the filler plug to make sure that there is a sufficient supply of lubricant.
2. Whenever a coupling is dismantled, inspect the teeth to see that they are in good condition. When the coupling is reassembled, check the alinement of the turbine and pump in order to guard against excessive coupling wear.

LUBRICATION. Lack of proper lubrication is the primary cause of most pump failures. Reciprocating engine-

driven pumps are usually lubricated by either sight-feed drip cups or wick lubrication. See that oil cups are filled with oil and that an adequate oil supply is being fed to the bearings.

Motor-driven pumps and some Diesel engine-driven pumps fitted with ball bearings are usually fitted for grease lubrication. Before starting, see that all grease cups and oil reservoirs are filled with lubricant and that no water or foreign matter is in the oil reservoir. Grease lubrication is used for the twofold purpose of lubricating the bearing, and excluding water and foreign matter from the bearing housing. Water pump shafts are usually fitted with water flingers between the pump shaft stuffing-box gland and the bearing housing. These flingers should be checked to see that water from the pump glands does not enter the bearing housing. Occasionally you will find that sleeves fitted on pump shafts do not fit the shaft tightly, and water leakage under the shaft sleeves may result. If such leakage exists, care should be taken to prevent water from entering the bearing housing.

Tests and Inspections

The following tests and inspections should be made on rotary pumps, and the results entered in the appropriate checkoff list or log:

DAILY: Turn idle pumps by hand.

WEEKLY: Lubricate the speed-limiting or speed-regulating, and overspeed trip governors. Run the pump under power. Lift all relief valves by hand. Check the operation of the discharge check valves (if installed). Check the condition of the lubricating oil; in particular, check for the presence of water in the lube oil.

QUARTERLY: Test all relief valves by steam, water, or oil, as appropriate. Measure thrust bearing clearances, and check the position of the pump rotors. Check the bearing clearance by leads or bridge gage readings. Examine and set up all foundation bolts, and secure all

foundation dowel pins. Check wear of internal pump parts by slowly closing the suction valve at the pump and noting the amount of vacuum pulled; if the pump fails to produce the required vacuum, it should be opened and repaired as necessary. (A vacuum of at least 12 inches Hg should be developed by fuel-oil service pumps, 15 inches Hg by fuel-oil booster and transfer pumps, and not less than 6 inches Hg by lubricating-oil pumps.) When making this test, see that the pump is filled with oil before closing the suction valve. Clean the lube oil system, and renew oil or grease.

ANNUALLY: Open the pump, turbine, and reduction gear casings for inspection and cleaning. Measure the clearances of all wearing plates and liners, casing throat bushing, rotors, casing liners, and bushings, and renew parts if necessary. Examine all pump rotors, shafts, bearings, timing gears and keys, turbine rotors and blading shafts, and reduction gears, particularly worms and worm wheels.

Safety Precautions

The following precautions must be observed in the operation of rotary pumps:

1. See that all relief valves, where fitted, are tested at appropriate intervals. Make certain that relief valves function properly at the designated pressure.
2. Never attempt to jack a pump by hand while the steam or power is on.
3. Do not tie down the overspeed trip, the speed-limiting governor, or the speed-regulating governor. Do not in any way render these devices inoperable.
4. Never operate a positive-displacement rotary pump with the discharge valve closed, unless the discharge is protected by a properly set and tested relief valve.

5. Check the setting of the overspeed trip, if fitte at least quarterly. See that the overspeed trips a set to shut off all steam to the unit when the rat speed is exceeded by 10 percent.
6. Check the setting of the speed-limiting and spee regulating governors, where fitted, at least qua terly. See that they are set to limit the speed of t unit to the rated speed, under rated conditions, a that the rated speed is not exceeded by more th five percent for any condition of loading.

CENTRIFUGAL PUMPS

Aboard ship, centrifugal pumps are used for main ci culating, condensate, fire, gasoline handling, cargo, fresh and salt-water services, and many other applications There are many types of centrifugal pumps, but a operate on the same principle. The operation of centrifugal pumps depends upon a force (centrifugal) which imparts a high velocity to the liquid pumped. This force is produced by the rotation of the impeller at high speed. The liquid is sucked in at the center or EYE of the impeller and discharged at the outer rim of the impeller.

By the time the liquid leaves the impeller, it has acquired a high velocity and kinetic energy. The liquid is slowed down by being led through a volute or through diffusion vanes. As the velocity of the liquid decreases, its pressure increases; in this way the kinetic energy of the liquid is changed to potential energy.

Figure 4–11 illustrates the internal parts of a small centrifugal pump; this pump is frequently used as a ship's service fresh-water pump, or as one of the distilling plant auxiliary pumps. (The pump shown in figure 4–11 is a single-suction, single-stage centrifugal pump. The suction casing surrounds the shaft and the water enters the pump impeller through the annular chamber surrounding the shaft. The pump shaft, supported at both ends by roller bearings, is usually found externally coupled to the driving motor.)

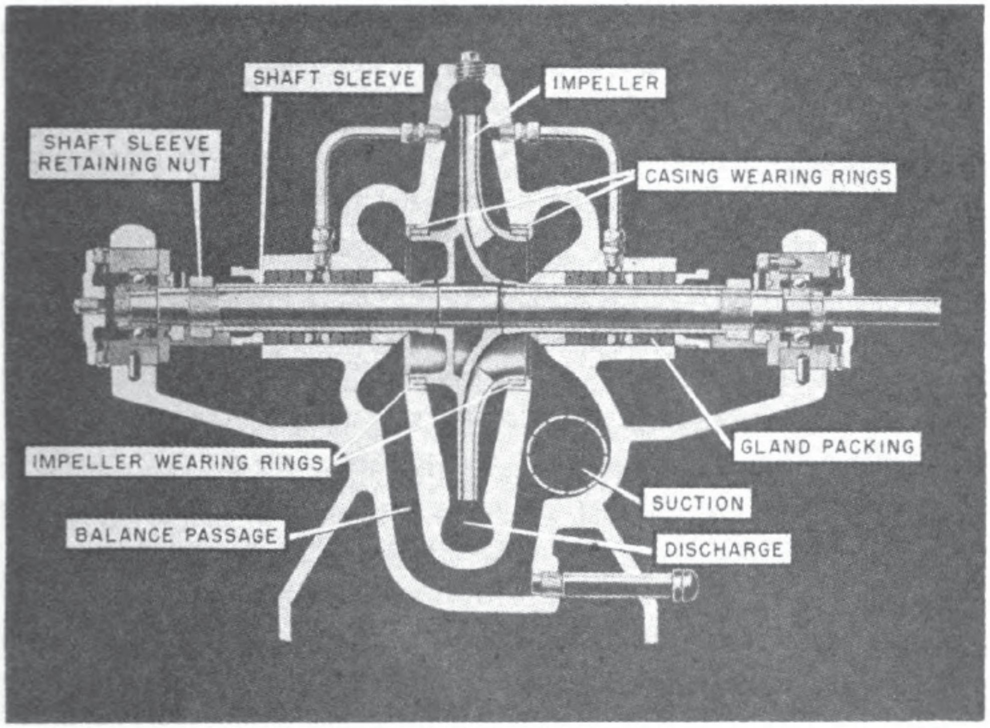


Figure 4–11.—Centrifugal pump parts.

Maintenance and Repair of Centrifugal Pumps

The tests, safety precautions, and maintenance factors for rotary pumps, outlined earlier in the chapter, are applicable in a general way to centrifugal pumps. However, some of the information which you must have in order to give proper care and maintenance to centrifugal pumps is given in this section. For additional information, as well as for specific information on any one pump, you should consult BuShips *Manual* and the appropriate manufacturer's technical manual. Before attempting to repair a pump, you should assemble the pump history and all pertinent drawings and dimensional data.

In a centrifugal pump, the portion of the shaft adjacent to the packing gland, and the casing-impeller sealing areas, are subject to wear during operation, and therefore must be renewed from time to time to maintain the operating efficiency of the pump.

To prevent having to renew the entire shaft solely

because of wear in the packing gland area, shafts in centrifugal pumps are often provided with tightly fitted renewable sleeves. To offset the need for renewing or making extensive repairs to the casing and impeller, these two parts are also provided with renewable wearing surfaces, called the casing wearing rings and the impeller wearing rings. (You can see the arrangement clearly in figure 4–11.)

When it is necessary to renew these parts, the rotor assembly, consisting of the pump shaft, the impeller and its wearing ring, and the casing rings, is usually brought into the shop. The method of replacing these parts is described in the paragraphs which follow. The repair parts generally are available from the ship's allowance of spare parts, but often it may be necessary to turn them out in the shop. However, before you can proceed with these repairs, the manufacturer's technical manual and applicable blueprints should be consulted to get the correct information on vital clearances and other data. If a manufacturer's technical manual or applicable blueprints are not available, you can obtain information on wearing ring clearances in chapter 47 of BuShips *Manual*, and shaft sleeve data in chapter 40, table B–3, of BuShips *Manual*.

RENEWING SHAFT SLEEVES. In some pumps, the shaft sleeve is pressed onto the shaft tightly by means of a hydraulic press, and the old sleeve must be machined off in a lathe before a new one can be installed. On other centrifugal pumps, the shaft sleeve is a snug slip-on fit, butted up against a shoulder on the shaft and held securely in place with a nut. In the latter case, the sleeve-shaft shoulder joint is usually made up with a hard fiber washer to prevent leakage of liquid through the joint and out of the pump between the sleeve and shaft.

REPLACING WEARING RINGS. The impeller wearing ring is usually lightly press-fitted to the hub of the impeller and keyed in with headless screws. To remove the

worn ring, withdraw the headless screws and machine the ring off in a lathe.

The amount of diametrical running clearance between the casing rings and impeller rings affects the efficiency of a centrifugal pump. Too much clearance will let an excessive amount of liquid leak back from the discharge side to the suction side of the pump. Insufficient clearance will cause the pump to "freeze." Before you install a new wearing ring on the impeller, measure the outside diameter of the impeller hub, the inside and outside diameter of the impeller wearing ring, and the inside diameter of the casing ring. If the measurements do not agree with the fit and the clearance data on hand, ask the leading PO for instructions before you proceed any further. Sometimes it is necessary to take a light cut on the inside diameter of the impeller ring in order to get its correct press fit on the impeller hub. The difference between the outside diameter of the impeller wearing ring and the inside diameter of the casing wearing ring is the diametrical running clearance between the rings. If this clearance is too small, it may be corrected by taking a cut on either the outside diameter of the impeller ring or the inside diameter of the casing ring. The concentricity of the two rings should also be checked; if they don't run true, their mating surfaces must be machined so that they do run true, bearing in mind, of course, to retain the specified diametrical clearance.

MEASURING BEARING CLEARANCES. In a centrifugal pump installation, fitted with an internal water-lubricated bearing inside the pump casing (such as condensate pumps), an adequate supply of clean water, for lubricating and cooling, must be supplied to the bearing. Several types of materials which have been used for internal water-lubricated bearings are as follows:

1. Laminated phenolic material grade FBM (Fabric base bakelite or micarta).
2. High lead content bronze.
3. Graphited bronze.

4. Lignum vitae bearings are also satisfactory. However, because these bearings are hard to install, their use is *NOT* recommended, except in an emergency.

The condition of all types of internal water-lubricated bearings should be checked frequently to guard against excessive wear which results in misalignment and possibly shaft failure.

As far as oil-lubricated sleeve or shell-type bearings are concerned, the bearing clearances should be measured with leads or by taking bridge-gage readings (where bridge gages are furnished) at least every 6 months. Maintain the clearances, within the limits shown on the manufacturer's plans. If such plans are not available, follow the instructions outlined in chapter 40, table B–4, of BuShips *Manual*.

When measuring the clearance of a bearing by taking leads, the following procedure is used:

1. Remove the upper half of the bearing.
2. Lay several lengths of soft lead wire circumferentially on the journal. Do not use hard fuse wire.
3. Replace the upper half of the bearing and set up on all bearing nuts. Mark the position of each one.
4. Remove the top half of the bearing; examine, and measure the thickness of the leads with a micrometer.

The best method of placing the leads on the journal is shown in figure 4–12. Leads should not be used which are heavier than required for the clearance to be measured. When taking leads, see that all bolts, bolt holes, bearing surfaces, liners (if used), and butting faces of the shells are free from foreign matter. When the leads have been properly placed and the bearing assembled, the nuts should be run down to bring the shells solidly against the liners (if used), or the metal-to-metal of butting faces. (Do not apply an additional force to the nuts because it may result in deforming the threads or straining the metal of the bolts.) When set up, the position of the bearing nuts should be marked so that they may be again tightened the same amount after the leads have been removed.

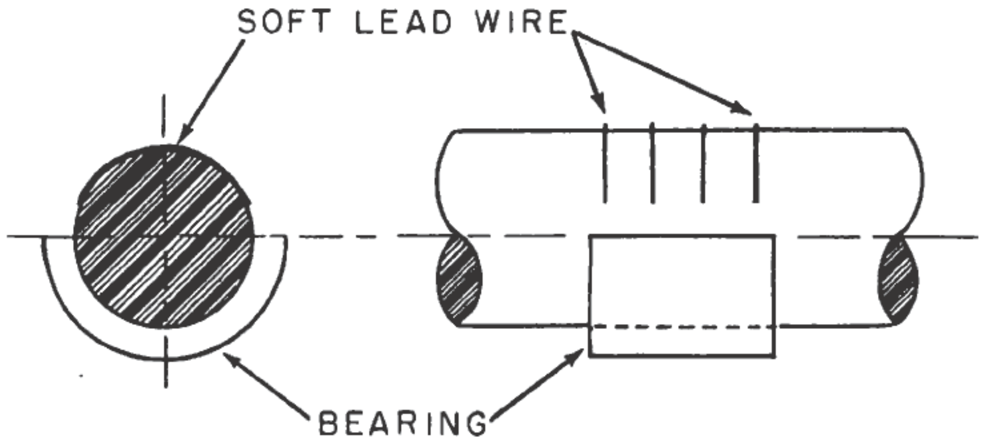


Figure 4–12.—Taking leads.

When the leads are removed from the journal, one end of each lead should be pinned to a piece of paper. The leads should be spaced the same distance apart and arranged in the same order as they were on the journal. If the lead is found to be squeezed out evenly along its entire length, the clearance is uniform. To determine the bearing clearance, measure each lead at, or near, its midpoint. The average thickness will indicate the bearing clearance, provided there is no great variation in the thickness of the individual leads. In addition, the thickness of each lead should be carefully measured at several places, with a micrometer, along the length of the wire. Leads which vary in thickness indicate an uneven bearing surface. Such bearings should be refitted to give uniform clearance.

FITTING AND SPOTTING-IN OF BEARINGS. To fit a bearing to its journal, coat the journal with thin, red lead and oil, or black lead and oil, or prussian blue. Lay one of the bearing halves on the journal and rotate it back and forth slightly. Remove the bearing half and examine the surfaces for high spots. The high spots are located in the area where the coloring compound has adhered to the bearing surfaces. These spots must be scraped. Continue to produce a smooth and even contact surface until the spots are uniformly distributed over the bearing surface, and cover such an area in order to indicate that practically

all of the surface is in contact with the journal. To ensure proper fitting of the bearing, repeat the above operations with the bearing in its proper position on the journal, and with the bolts in place and properly set up. With large bearings or with bearings that are not easily accessible, use a mandrel the exact size of the journal. During the finishing operations, you should, as a final check, spot the bearing to the journal. After the bearing has been spotted in, take leads to determine if the bearing clearance is satisfactory. When the clearance is satisfactory, record the final clearance in the Machinery History.

In scraping in a bearing, care must be taken that the lining is concentric with the shell. (If the concentricity of a bearing is lost, the pump shaft may become misaligned. This will cause unequal loads on the bearings along the shaft, and is also likely to destroy the clearances between the casing wearing rings and the impeller wearing rings.)

With very small bearings the amount of clearance is often determined by "feel." These bearings should be fitted as previously described and assembled on their journals with the bearing nuts set up hard. If the clearance is correct, there will be only the slightest indication of play between the bearing and its journal, and the journal will revolve easily.

Major Troubles and Repairs

A list of the principal troubles that may occur with centrifugal pumps, together with their causes, is given below. In the majority of cases, the trouble is external to the pump, and these causes should be carefully investigated before undertaking repairs:

1. FAILURE TO DELIVER WATER:
   a. Pump not primed.
   b. Insufficient speed.
   c. Impeller plugged.
   d. Wrong direction of rotation (this may occur after motor overhaul).

2. SHORT IN CAPACITY:
   a. Air leaks in stuffing boxes.
   b. Insufficient speed.
   c. Insufficient suction head for hot water.
   d. Suction strainers fouled.
   e. Impeller partially clogged.
   f. Mechanical defects: wearing rings worn; impellers damaged; and casing packing defective.
3. PRESSURE LOW:
   a. Insufficient speed.
   b. Air leaks.
   c. Incorrect discharge valves open in manifold (this may allow the pump to discharge into an open line, causing the pump to operate at other than the design point).
   d. Mechanical defects, same as 2.f., above.
4. PUMP LOSES WATER AFTER STARTING:
   a. Leaky suction line.
   b. Water seal plugged.
   c. Suction lift too high (often caused by fouling of the strainer after the pump is started).
   d. Air or gases in water.
5. PUMP OVERLOADS DRIVER:
   a. Speed too high.
   b. Liquid of different specific gravity and viscosity higher than normal.
   c. Rubbing caused by foreign matter in the pump, and between the case rings and impeller.
   d. Mechanical defects: rotating element binds; shaft bent; and worn bearings.
6. PUMP VIBRATES:
   a. Misalignment.
   b. Poor foundation.
   c. Impeller partially clogged, causing unbalance.
   d. Mechanical defects, same as 5.d., above.

If the pump fails to build up pressure when the discharge valve is opened and the pump speed increased, proceed as follows:

1. Secure the pump.
2. See that the pump is primed and that all air is expelled through the air cocks on the pump casing.
3. See that all valves on the pump suction line are open.
4. Start the pump again. If the discharge pressure is not normal when the pump is up to its proper speed, the suction line may be clogged, or an impeller broken. It is also possible that air is being drawn into the suction line or into the casing. If any of these conditions exist, stop the pump, try to find the source of the trouble, and correct it, if possible.

The parts of a centrifugal pump most frequently requiring repair or replacement are:

1. CASING RINGS AND IMPELLER RINGS. Since the purpose of these rings is to keep the internal bypassing of the liquid to a minimum, the clearances should be checked and restored when worn beyond allowable limits, whenever the pump casing is opened up, and at least once each year.

2. SHAFT SLEEVES. There is a common tendency of operating personnel to take up too hard on the packing in an attempt to prevent stuffing box leakage. This causes scoring of the shaft sleeves. Whenever the pump is opened, the sleeves should be examined and if not badly scored, they should be smoothed up; if they are badly scored, they should be replaced.

3. BEARINGS. Worn sleeve bearings cause the rotor to drop; this, in turn, results in wearing of the casing and impeller rings. Bearings of centrifugal pumps should be rababbitted in accordance with the table in chapter 40 of BuShips *Manual,* when bridge gage readings or leads indicate that maximum allowable wear has occurred. (The oil clearances for bearings can be obtained from the manufacturer's plans or technical manual. If such data are not available, refer to the table of tolerances and clearances in chapter 40 of BuShips *Manual.*)

Whenever a bearing is opened up, it should be inspected carefully for ridges, scores, and wear. See if the bearing lining is firmly anchored to the shell. If the bearing is scored, uneven, considerably worn, or the lining loose, the bearing should be replaced with a spare.

Journals should be kept free from rust, and even at all times. To remove rust spots, ridges, and sharp edges of scores, the journals should be lapped with an oilstone, or with an oilstone powder.

4. BUSHINGS. Whenever a pump is opened up, bushing clearances should be measured. Bearing wear will probably cause bushing wear, and the bushing should be renewed if the bearings are restored to their original readings.

MAINTENANCE AND REPAIR VALVES AND PIPING

Aboard ship you are responsible for the routine maintenance of valves, and piping assemblies in your assigned spaces. In addition, the qualifications for advancement in rating require that you know how to make minor repairs to insulation or lagging in piping; how to reface valve seats and disks; and how to repack high-pressure valves. Unless the piping system and valves are in good condition, the connected units of equipment and machinery cannot be operated efficiently, and the safety of the ship's personnel may be imperiled.

This chapter covers the principal difficulties encountered with valves and the repair of piping systems. Additional information can be obtained from either *Machinist's Mate 3,* NavPers 10522 or *Fireman,* NavPers 10520–A.

Valve Maintenance

Valves as well as other units of equipment require proper care and maintenance. The principal difficulties encountered with valves are leakage past the seat and disk, leakage at the stuffing box, sticky valve stem, and

a loose valve disk. You should know how to prevent and correct these troubles.

VALVE LEAKAGE CAUSES AND REMEDIES. Valve leakage is generally a result of the disk and the seat failing to make a tight joint, and this failure may be due to one of the following causes:

1. Foreign substances (scale, dirt, waste, or heavy grease) are lodged on the seat in such a way that the disk cannot be seated. If the obstructing material cannot be blown through, the valve will have to be opened and cleaned out.
2. Scoring of the seat or disk has been caused by attempts to close the valve on scale or dirt, or by corrosion. If the damage is slight, the valve should be made tight by grinding the disk together with the seat; if the damage is extensive, a cut will have to be made on the disk, and the valve seat ring may have to be renewed before it is ground.
3. The disk may not seat properly because of a bent spindle guide, or a bent valve stem.
4. The valve body or disk may be too weak for the purpose for which it is used, causing distortion of the valve seat or disk under pressure.
5. In bronze valves fitted with seat rings, leakage through the valve may occur as a result of leakage around the threads of the seat rings. To correct this defect, remove the seat ring, clean the threads, and remake the joint. It may be necessary to recut the threads in the valve and to renew the seat ring to secure tightness.

STUFFING BOX LEAKAGE. Stuffing box leaks can be remedied by setting up on the gland, or by repacking it. The gland must not be set up on nor packed so tightly that the stem binds. If the leaks persist after either or both of the remedies are applied, a bent or scored valve stem may be the cause. Considerable trouble with stuffing box leaks can be avoided if valves are installed with the valve stem pointing upward.

In repacking the stuffing boxes, successive turns of the packing material are placed around the valve stem. Where string packing is used, it is coiled around the rod. The ends are beveled off to make a smooth seating for the bottom of the gland, which is then put on and set up by the bonnet nut, or the gland bolts and nuts. To prevent the string packing from folding back when the gland is tightened down, the packing should be wound in the same direction as the gland nut is turned. In this way there are no joints in the packing, and leakages are less likely to occur. Where successive rings are used, the ends of the packing rings should be cut square and even, and the ends butted to make a level joint. The different rings should break joints. If the rings are put in place with packing sticks, care should be taken not to split the packing.

Gate, globe, angle, and stop-check valves for all pressures are so constructed that the stem is back-seated against the valve bonnet, when the valve is fully open. This enables one to repack the stuffing boxes under pressure, when necessary. High-pressure valves are provided with a pipe plug as a leak-off to the cooling chamber, and this pipe plug should be removed when repacking the valve under pressure. For valves where discharge cannot be permitted during repacking under pressure, the discharge should be blanked off securely before the valve is opened for the back-seating and repacking.

STICKING VALVE STEM. The sticking of valve stems may be caused by the stuffing box being set up on or packed too tightly. To correct this fault, it is only necessary to slack up on the gland to relieve the packing pressure. If the stuffing box gland is warped, as a result of uneven setting up of the gland nuts, balance the settings of the gland nuts.

Paint or rust on the valve stem should be removed by cleaning the stem.

Jamming the valve shut while it is cold results in the disk being bound tightly to the seat because of expansion

of the valve stem, caused by subsequent heating. To relieve this strain, carefully slack off the yoke nuts; if it is not a yoke valve, slack back slightly on the bonnet nuts. This generally permits the disk to be freed from the seat. (The line should have no pressure when slacking off the yoke nuts.)

Jamming the valve open while it is hot may result in the valve being bound open because of contraction of the valve stem. This condition is not serious, as the valve can usually be started by means of a wrench, though care must be taken not to spring the valve stem. If a valve has been opened wide, turn the stem a half revolution in the closing direction in order to eliminate the danger of valve binding due to expansion.

The valve may become stuck if the valve stem threads are burred from rough handling, or upset from pressure which has been applied to move sticking valves. This condition is the most serious of all valve stem troubles. If the valve can't be moved by any other method, the bonnet must be removed, the stem cut out of the yoke or bonnet, and a new stem made. If the bonnet and yoke are damaged, they must be replaced. If the burred or upset threads are detected before the stem becomes stuck, they can be dressed smooth with a file, or machined in a lathe.

If the sticking is due to a bent valve stem, the stem must be either straightened or renewed.

Loose valve disk. When a valve disk comes loose from its stem, the cause is either failure of the securing device or corrosion through the stem. The first cause is infrequent in valves of good construction, and recurrence can be prevented by minor adjustments or by greater care in reassembling valve parts. Corrosion of the valve stems occurs mostly to valves installed in salt-water lines. Stems which have shown signs of corrosion should be inspected periodically so that replacement can be made before failure occurs. Replacements should be made with rolled Monel-metal stems. In order to prevent failure

caused by corrosion, split pins in valve disks in water lines should be of nickel-copper alloy instead of iron, steel, or brass.

Valve Repair

In repairing valves, a knowledge of the materials from which they are made is essential. Each material has its limitations of pressure and temperature; therefore, the materials used in each type of valve depend upon the temperatures and pressures of the fluids which they control.

The piping materials commonly in use fall into three basic groups—brass, iron, and steel. Iron valves are further subdivided into three grades: cast, malleable, and steel. Steel valves are either cast or forged, and are made of either plain steel or alloy steel. Alloy steel valves are used in high-pressure, high-temperature systems; the disks and seats of these valves are usually surfaced with a chromium-cobalt alloy known as STELLITE. This material is extremely hard.

Brass and bronze valves are never used when temperatures exceed 550° F. Steel valves are used for all services above 550° F. and for the lower temperatures where conditions, either internal or external, such as high-pressure, vibrations, or shock, may be too severe for brass or iron. Bronze valves are used almost exclusively in systems carrying salt water. The seats and disks of these valves are usually made of Monel, an excellent corrosion- and erosion-resistant metal.

Valve repair, except for routine packing, is generally limited to overhaul of the seat and disk. However, all other parts of the valve must be inspected and, if found to be defective, must be repaired or replaced. The valve seat and the valve disk should be closely inspected for erosion, cuts on the seating area, and improper fit of the disk to the seat. If the valve disk and the seat appear to be in good condition, they should be spotted-in; this determines whether they actually seat properly. You should

know how to install, reface, grind, spot-in, and, when necessary, lubricate valves. Detailed information on spotting-in, grinding, lapping, and refacing procedures can be obtained from either *Machinist's Mate 3*, NavPers 10522 or chapter 47 of BuShips *Manual*. However, additional information concerning refacing, grinding, spotting, and surfacing by welding is covered in the sections which follow.

REFACING, GRINDING, AND SPOTTING. If the valve seat or disk are scored badly, they should be refaced either in a lathe or with a reseating machine. The latter method is preferable for the valve seat, as the work can be done with the valve body in place. The disk should be refaced in a lathe. Following the refacing, the seat and disk are ground together with an abrasive such as grinding compound or powdered emery. The disk is turned back and forth on the seat, occasionally lifted from its seat, and position shifted slightly. Grinding should be continued until a bearing all around is obtained. As a test of the work procedure, place pencil marks at intervals of about one-half inch on the bearing surface of the valve disk or seat. Drop the disk on the seat and rotate it about one-quarter of a turn. If all the pencil marks rub off, the seating is satisfactory.

Grinding may be difficult with heavy valves which are placed upside down or at an angle. In such cases, it is best to use a jig to guide and support the disk, otherwise it will be almost impossible to obtain satisfactory results. Some valves when ground cold will not be tight when heated; the only solution is to grind the valve while hot. Heating can be accomplished either with a torch or by keeping a ring of red-hot metal in contact with the disk.

SURFACING BY WELDING. In several cases, the use of high-temperature high-pressure steam has resulted in serious wear and erosion of the valve parts, such as seat rings and disks, exposed to the steam. To prolong the life of these parts a process of surfacing by welding with a suitable heat-resisting alloy (such as cobalt-chromium

to specification 46R5 or an approved alternate alloy) is recommended. An advantage of this process is that damaged weld metal can be removed by grinding and new material can be applied, thus retaining the original valve parts in service for a considerable time, and eliminating the expense and time required to manufacture entirely new valve parts. Minor defects may be removed by grinding to the extent of the thickness of the original welded surface. However, grinding of one welded surface against another does not produce the most satisfactory seating surface and, therefore, should be avoided. The valve disk may be removed by grinding with machine tools; however, if it is impracticable to remove the valve body, grinding of the seat ring should be accomplished by using grinding compound and a cast-iron dummy disk machined to the angle required. In some cases this angle may differ 1° or 2° from that of the disk. Detailed drawings of the valve should be referred to, for this information. The dummy disk will require occasional machining to retain its proper angle and remove overlapping shoulders, which cause irregularities.

Piping System Repair and Maintenance

Reasonable care must be given the various piping assemblies as well as the units connected by the piping. In maintaining piping systems in satisfactory condition, the most important factor is to keep the joints, valves, and cocks tight. To ensure this, it is necessary to make frequent inspections of the lines.

When a ship is in operative status, quarterly tests should be made on the main and auxiliary feed systems and on all salt-water piping. These tests must be conducted under full working pressure, and must be carried on for a period of time long enough to disclose any leaks or other defects in the system.

On ships in reserve or inoperative status, piping systems are never put under pressure for testing purposes only. However, care must be taken to see that piping not

in use is kept thoroughly drained. The piping on any ship should never be used for securing chain falls, for supporting weights, or as hand or foot holds.

Where piping passes through decks or bulkheads, and there is a possibility of movement of one with respect to the other, stuffing boxes or flexible bulkhead connections are provided—if expansion bends or other offsets are not provided in the piping—to take up the movement. The exterior piping surfaces can be protected against external corrosion by keeping the surfaces properly painted and free of moisture. Graphite or asphaltum paint makes an excellent preservative for exterior piping surfaces. Piping in bilges, voids, and ballast tanks should not be painted unless it is of steel or iron, unprotected by galvanizing. In general, copper and brass piping should never be painted.

Continual leakage at a joint where a branch line joins another line is generally due to improper alignment. When joints are out of line, the pipe should be realigned so that flanges, screw threads, and unions meet properly without forcing. A slight alteration in the anchorages, connections, hangers, or piping leads, to allow the required expansion and prevent strain, or the fitting of supports which will prevent vibration, will often be sufficient to correct leaky joints. On some flange joints it may be necessary to reface the flanges or to fit distance pieces. Small leaks in gaskets should be checked immediately, since a dangerous blowout may result from progressive growth of the leak.

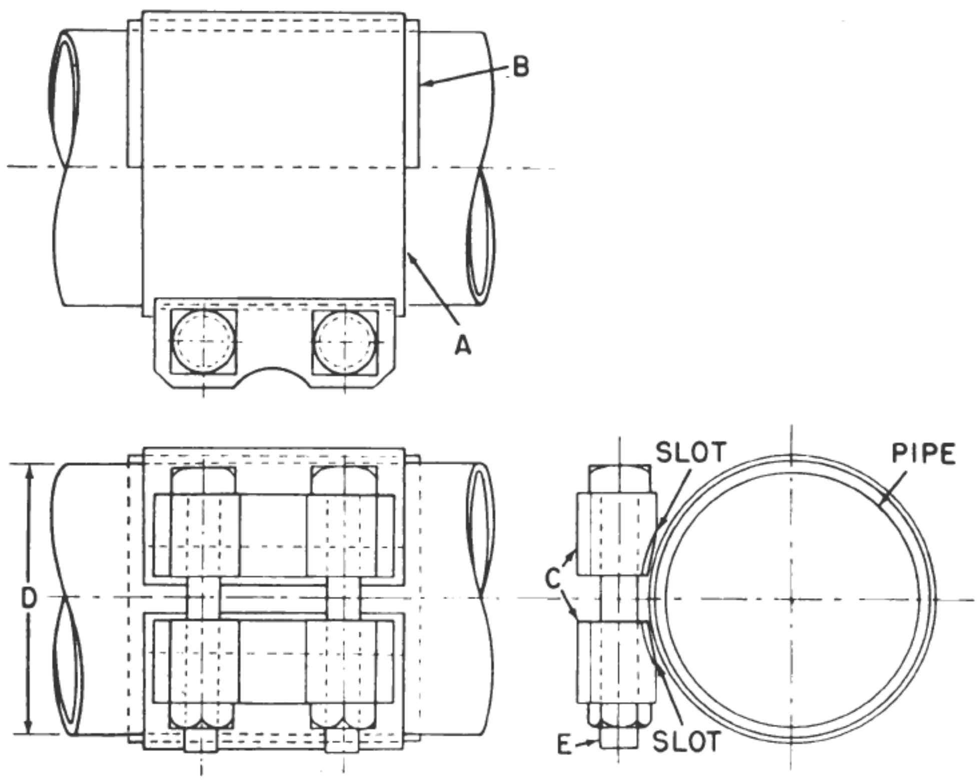
TEMPORARY REPAIRS. Repairs of a temporary nature can be made by securing a patch over the leak. The material used for the patch depends on the purpose for which the piping is used. It is considered good practice to make the patch from the same material as is used for flange gaskets of the piping. Back up the patch with a piece of sheet metal and secure with metal bands.

For low-pressure salt-water piping, red lead putty wrapped with canvas and served with marlin or electric

friction tape makes a satisfactory patch. A small leak in salt-water piping can be stopped by driving in a soft pine plug. The moisture will cause the wood to swell and remain in place.

Portland cement patches can be cast in place and secured by the band method, or they can be cast entirely around a low-pressure water line. Iron cement can be used effectively on iron and steel piping carrying low pressure.

To remedy a defect in practically any size piping, a universal soft patch device, shown in figure 4–13, can be



NOTES

1. ITEM A TO BE 20- OR 22-GAGE SHEET METAL.
2. ITEM B TO BE SHEET RUBBER ONE-EIGHTH INCH THICK.
3. ITEM C TO BE STEEL OR COMPOSITION. ONE SET ADAPTABLE TO NEARLY ANY SIZE PIPING (SLOTTED FOR ITEM A).
4. DIAMETER D OF PIPING NEED NOT BE FIXED SINCE BY CHANGING ITEM A, ANY SIZE OF PIPING MAY BE ACCOMMODATED.
5. CLAMPING BOLTS ARE ONE-HALF INCH IN DIAMETER.

Figure 4–13.—Soft patch device.

applied. This device has been tested on piping of various hole sizes, and has satisfactorily withstood pressures from 100 to 300 psi.

Emergency repair clamps similar to those shown in figure 4–13 and emergency couplings can be found in repair lockers. If no emergency repair clamps are available, they can be readily made.

SEMIPERMANENT REPAIRS. These repairs are generally made by serving the piping with tightly drawn wire, soldered or brazed as it is applied. Several layers of wire securely bonded give a strong, tight repair. Semipermanent repairs can also be made by forming a mold of sheet metal bent entirely around the piping at the leak, making joints tight with fire clay and pouring in a mixture of available soft metal such as lead, babbitt, or zinc. This work should be done with the section of piping removed from position and placed vertically, the leaks temporarily stopped with soft solder, lower end blank flanged, and the piping full of water to a point above where the cast is to be made. Otherwise the heat of the casting will expand the piping, which on contracting will draw away from the casting.

PERMANENT REPAIRS. Small holes may be plugged with a rivet or a screw. Soft solder patches are seldom permanent, especially on piping subject to expansion and contraction, or vibration.

To make permanent repairs on sections of leaky copper or brass tubing, the piping should be removed and the defect closed by brazing.

INSULATION OF PIPING. Copper, copper-nickel alloy, and brass piping in bilges must not rest in contact with the iron or steel components of the ship. All securing brackets and hangers for this piping should be lined with sheet lead or with some other soft metal, to prevent hardening of the piping or squeezing when tightening up on the brackets.

Bulkhead flanges for all steam piping should be insulated to prevent the transfer of heat to the bulkhead

(fig. 4-14) with an approved heat-resisting material not affected by water, and capable of sustaining, without crushing or injury, the compression produced by the bolts to secure watertightness.

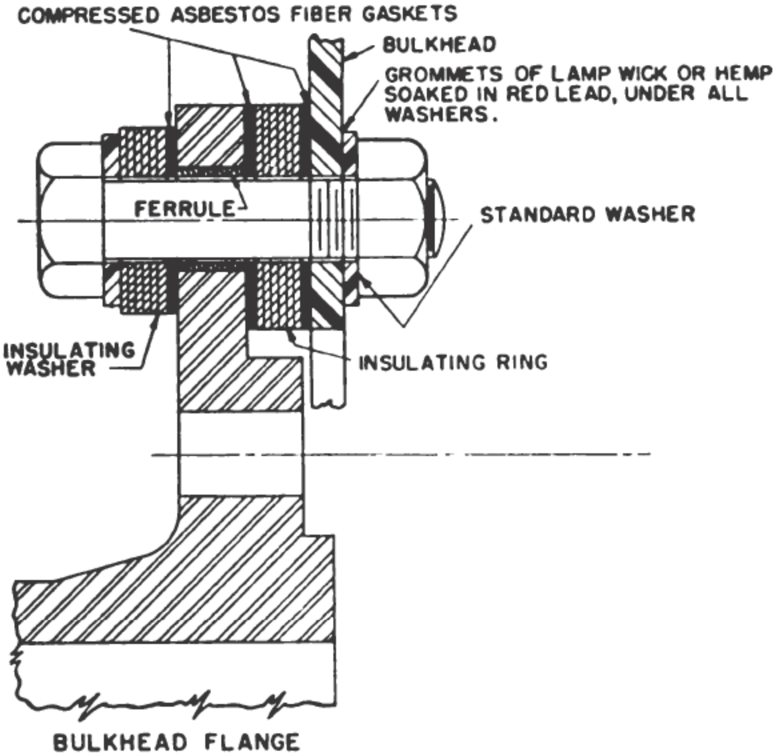


Figure 4-14.—Insulation of bulkhead flange.

The compressed asbestos fiber gaskets may be omitted if the insulation used is a satisfactory joint material for watertightness. The bolts should be insulated with approved ferrules, or instead of ferrules, approved asbestos valve stem or sheet packing wrapped around the bolts may be used. Bulkhead flanges for all pipes conveying salt water should be electrically insulated from the bulkhead, as shown in figure 4-14, with fiber or other electric insulation (sheet rubber, cloth insertion, Navy Department Specifications 33-P-8, or approved equivalent). The insulating ring and washer should be one-eighth inch thick and the bolt ferrule one-sixteenth inch thick. (Gaskets may be omitted as mentioned above.) Flange joint bolt

holes and those used for bulkhead joints not requiring insulation must have bolt holes drilled to suit the insulation around the bolts. The pipes which pass through electrically insulated bulkhead flanges should be electrically grounded to the metal hull of the ship, either by connections made at their ends to the hull or grounded equipment or fittings.

RENEWAL OF SALT-WATER PIPING. In the renewal of nonferrous piping systems, copper-nickel alloy piping should be used. In ferrous or nonferrous piping systems, replacements should be made in kind, i.e., using the same materials and protective coatings as found in the remainder of the system. However, if excessive maintenance has been performed, copper-nickel alloy piping may be used, provided the substitution is specifically approved by BuShips.

QUIZ

1. What will ensure even wear throughout a cylinder of a reciprocating pump?
2. What is generally indicated by a heavy metallic knock in the steam cylinder of a pump?
3. How is the length of the stroke adjusted?
4. If a reciprocating pump is frozen, how can you determine if there is excessive friction?
5. If a reciprocating pump has been operating properly and loses pressure on one stroke, what is the probable cause?
6. Before repairing or examining a reciprocating pump, what step should be taken?
7. What are the chief causes of a steam or water piston working loose on the rod?
8. Before fitting and installing Tuck's, flax, or other types of soft packing in a pump, what step should be taken, if practicable?
9. Troubles in the steam cylinder of a reciprocating pump result chiefly from what source?
10. When replacing piston rings on reciprocating pumps, what is the first step that must be taken?

11. How are rotary pumps designed to minimize slippage from the discharge side back to the suction side?

12. What must be done when rotary pump bearings are worn excessively and it becomes necessary to renew the bearings?

13. What procedure must be taken to see that rotary pumps, fitted with timing gears, have the correct clearance between the two pumping rotors during operation?

14. How often should thrust bearings on a rotary pump, as well as the position of rotors, be checked?

15. What is the primary cause of most pump failures?

16. If a rotary pump fails to produce the required vacuum, what should be done?

17. What is the purpose of a shaft sleeve on a centrifugal pump?

18. Why are centrifugal pumps provided with replaceable wearing rings?

19. How is an impeller wearing ring keyed to the impeller hub?

20. Why is excessive clearance between casing wearing rings and impeller wearing rings objectionable?

21. How often should clearances of oil-lubricated shell-type bearings be checked?

22. When measuring the clearance of a bearing by taking leads, what step is first taken?

23. In scraping a centrifugal pump bearing, why must care be taken to see that the lining is concentric with the shell?

24. If the suction strainers of a centrifugal pump are fouled and the impeller is partially clogged, what will probably result?

25. If the speed of a centrifugal pump is high and the pump is binding, what will be the probable result?

26. What centrifugal pump parts require repairs or replacement most frequently?

27. What should be done with a slightly scored valve seat and disk?

28. In order to avoid stuffing box leaks, what is the best position in which to install a valve?

29. If the stuffing box is set up or packed too tightly, what is likely to result?

30. Corrosion of valve stems occurs mostly to valves installed in which lines?
31. What should be done with a badly scored valve seat and disk?
32. On ships in an operative status, how often should the main and auxiliary feed systems and all salt-water piping be tested?
33. What preservatives are recommended for exterior surfaces of piping?
34. If a small leak in a gasket of a piping joint is not remedied as soon as possible, what may be the result?
35. How should permanent repairs of leaky copper or brass piping be made?
36. How should securing brackets and hangers for copper-nickel alloy and brass piping in bilges be lined?
37. When replacing nonferrous salt-water piping, what kind of piping should be used?

CHAPTER 5

OPERATION AND MAINTENANCE OF REFRIGERATION EQUIPMENT

As a Machinist's Mate 3, you have been introduced to the equipment used aboard ship for refrigeration and air conditioning purposes. As a Machinist's Mate 2, you will be held responsible for having a thorough knowledge of the operating principles and the construction of refrigerating equipment. You must be familiar with the characteristics of the refrigerants commonly used, and be able to operate and maintain refrigerating equipment. Through experience and study, you have already gained some of the knowledge and abilities necessary to meet the requirements for advancement; additional experience and further study will be necessary. The information in this chapter deals with the operation and maintenance of Freon–12 refrigeration equipment. This information is provided to serve as an aid as you continue to study for advancement.

Basic information on refrigeration is given in *Fireman,* NavPers 10520–A; the principles of operation and details of the construction of refrigeration equipment are given in *Machinist's Mate 3,* NavPers 10522. It may be helpful if you review the material in those two sources before you study the information in this chapter.

OPERATING PROCEDURES FOR FREON–12 SYSTEMS

Since Freon–12 plants used for refrigeration and those used for air conditioning are basically the same, the fol-

lowing information on operating procedures applies, in general, to refrigeration equipment used for either purpose. Detailed instructions for the operation of a particular plant should be obtained from the manufacturer's technical manual.

When a refrigeration or air conditioning system is being prepared for starting, the procedures (AS APPLICABLE to a particular installation) are as follows:

1. Open all refrigerant system valves except the following: Those valves which lead to the atmosphere; the bypass valves around the liquid-control valve assemblies and the suction-pressure control valves; the dehydrator-cutout valves; the compressor-suction line valves; the compressor-discharge line valves; the condenser-outlet valve; the liquid-receiver outlet valve; and the stop valves in the condenser cross-connecting lines (if installed).
2. Start the fan motors on all forced-air coolers; see that an adequate amount of air is being delivered.
3. On water-cooler applications (soda fountains, drinking-water coolers, process-water coolers), admit the water to be cooled and purge the water circuit of air.
4. See that all stop valves in the circulating-water supply and in the discharge lines for the Freon–12 condenser are open.
5. If water is taken from the fire main, make certain that the pressure-reducing valve ahead of the water-regulating valve is adjusted to provide a water pressure of 30 psi or less ahead of the water-regulating valve.
6. When no pressure-reducing valve is installed, regulate the fire-main connection stop valve manually so that the required water pressure ahead of the water-regulating valve is maintained.
7. When an individual circulating pump is used to supply condenser circulating-water, be sure that any valves which permit transmission of pump-

discharge pressure to the water-failure switch are open.

8. If the compressor unit is equipped with an air-cooled condenser, make certain that the air-flow passages to the condenser are unobstructed, and that the air-circulating fans are clear.
9. Open the compressor discharge-line valve, the stop valve in the line connecting the condenser and the liquid receiver, and the main liquid-line valve.

Starting The Compressor; Operation in Manual

Too much stress cannot be placed on the need for thoroughness and care at the time the compressor is started. Bent crankshafts, distorted valves, and blown gaskets are a few of the casualties which may occur if proper procedures and applicable precautions are not followed. After accomplishing or checking the items listed under prestarting instructions, proceed as follows:

1. Set the "automatic-manual" selector switch in the MANUAL position.
2. Close the maintaining-contact "start" button in the pump control circuit to prepare the pump motor for starting.
3. Close the momentary-contact "start" switch in the compressor control circuit to start the pump motor and to energize the "King" solenoid valve circuit.

   As the pump circulates the water, the water-failure switch closes automatically and completes the circuit to the compressor-motor contactor coil. When this circuit is closed, the compressor motor starts. In installations where a pump motor and a pump control circuit are not installed, closing the momentary-contact "start" switch energizes the compressor control circuit and starts the compressor motor.
4. Start and stop the motor and compressor several times, by normal control, to check their operating condition.

5. After it has been determined that the motor and the compressor are in operating condition, crack the suction stop valve and set the controls on automatic. This arrangement will eliminate the possibility of the pressure in the system from decreasing below that of the atmosphere and drawing air into the compressor.

   Crack the compressor-suction valve slowly, with the compressor running, so as to limit the quantity of suction gas handled by the compressor. The suction gage should be watched as the compressor-suction valve is opened. The valve should be opened, gradually, at a rate such that there will be neither a rapid fluctuation in suction pressure nor a rapid drop of pressure in the compressor crankcase.

6. If lubrication of the compressor is by forced feed, check the pressure on the oil-pressure gage.

   Unless specific instructions indicate otherwise, the oil pressure should be between 15 and 30 pounds above compressor-suction pressure within a few seconds after the compressor is started.

7. Make certain that the proper quantity of circulating water is flowing through the condenser before the compressor-discharge pressure reaches 125 psi.

In systems not equipped with water-regulating valves, normal operating conditions generally produce condensing pressures of less than 125 psi, since the condensing-water temperature is usually less than 85° F. In systems equipped with water-regulating valves, the valves should be adjusted to maintain the condensing pressure at 125 psi. When the valves are so adjusted, the quantity of cooling water required decreases rapidly with decreasing circulating-water temperatures. In systems equipped with air-cooled condensers, condensing pressures may exceed 125 psi when the temperature of the surrounding air is higher than normal.

Notes On Operating a Freon–12 Plant in Automatic

After the prescribed operating pressures and temperatures have been established with the selector switch set at MANUAL, the switch should be set in the AUTOMATIC position. When the switch is in position for automatic operation, the suction-pressure control is so connected, by electrical means, that it starts and stops the compressor automatically, on the basis of load conditions. If the automatic-control valves and switches are in proper adjustment, the operation of the plant, after proper starting, will be entirely automatic.

When the selector switch is set for automatic operation, the closing of the water-failure switch, the high-pressure switch, or the low-pressure switch through automatic operation will energize their respective circuits. Other control devices require the intervention of an operator before the compressor can be restarted. Certain high-pressure switches are provided with manual-reset devices which must be reset by the operator after the switches have been opened by excessive pressure.

OPERATIONS WITH FIRE MAIN WATER SUPPLY.—Some installations are designed so that the supply of condenser cooling water is available either from a centrifugal pump or from the fire and flushing main directly. If cooling water is obtained from the fire and flushing main instead of from the pump, the controller pilot-circuit pump-switch is opened manually when it is desired to deenergize the pump electrical circuit, and stop the pump motor. The water-failure switch remains closed, whether or not the compressor is in operation.

CIRCULATING-WATER FAILURE.—Should the flow of circulating water to the condenser be accidentally interrupted while the compressor is in operation, the decrease in water pressure will cause the water-failure switch to open. This deenergizes the compressor-motor line contactor-coil, opens the line contactors in the motor power-supply lines, and stops the compressor.

EXCESSIVE CONDENSING PRESSURE.—When the compressor discharge-pressure becomes abnormally high, the high-pressure cutout switch opens, deenergizing the line contactor-coils and stopping the motors (in the same manner as the opening of the water-failure switch does). When the condensing pressure returns to normal, the high-pressure switch closes and restarts the plant.

CIRCULATING-WATER CONTROL.—Condensers are sized so that excess water velocities will not be produced under maximum compressor loading. Suitable precautions should be taken to assure that the condenser does not have excessive water quantities. Larger than normal quantities of circulating water produce correspondingly higher velocities in the water flowing through the condenser tubes. These higher velocities increase the erosion of the tubes and of the tube-sheet surfaces. If manual control of circulating-water flow is required, it should be accomplished by manipulation of the valve in the overboard-line from the condenser.

ACTION OF OVERLOAD RELAYS.—The power required to drive a given compressor is in relation to the suction pressure, assuming that the discharge pressure is constant. An increase in suction pressure results in higher compressor capacity and higher power requirements. When large increases in suction pressure occur in a plant designed for low suction pressure, the increased condenser loading (caused by increased compressor capacity) raises the condensing pressure, and the compressor tonnage capacity increases faster than the horsepower-per-ton decreases; thus, the total required horsepower input to the compressor is increased. When the refrigerating compressor of a new plant is first started and when the compressor of an old plant is started after a prolonged and complete shutdown, the compartments to be cooled are warm; the refrigerant evaporating-pressure will, therefore, be much higher than normal. Under these conditions, the compressor motor may be overloaded;

the unit should be observed carefully, therefore, during its first few hours of operation.

Should the compressor or the pump motors become overloaded to a dangerous degree while the plant is in operation, the overload-relay switches will be opened by overload devices located in the power lines to each motor. When either of the overload-relay switches open, the control-relay switches open and stop the motors. The overload relays must be reset before the motors can be operated again under automatic control. If either of the motors should develop a short circuit, the line fuses will usually blow before the overload relay trips out. Should the overload trip fail to function, it will be necessary to stop the compressor motor with the manual control when overheating occurs.

COMPRESSOR SHORT-CYCLING.—The heat load of a refrigeration plant (that is, the amount of heat to be absorbed by the plant), regardless of the purpose for which refrigeration is required, will generally vary within wide limits; this variation will depend upon such factors as ambient temperatures, condenser cooling-water temperatures, frequency of opening doors and hatches of compartments to be cooled, and the number of men in compartments to be cooled. The heat load of a cold-storage refrigerating plant is sometimes more than doubled when warm supplies, unfrozen meat, etc., are charged into the cold-storage spaces in large quantities. The compressor unit must be designed to carry the maximum required heat load; it will operate at a fraction of its rated capacity, therefore, during a large part of its operating time. If the system's heat load is very small, the compressor need operate during only a small portion of the total time. When the compressor starts under a small load, the amount of refrigerant fed to the cooling coils may be even less than that required for the designed capacity of the machine at low-suction pressure. Under these conditions, the compressor rapidly reduces the suction pressures to the point where the low-pressure control

switch opens and stops the unit; that is, the compressor short cycles. The tendency of the compressor to short cycle may be decreased by increasing the range between the cut-in and cut-out points of the low-pressure control switch; or preferably, by reducing the capacity of the compressor. The capacity of the compressor may be reduced by one of several different methods.

In most Freon–12 refrigerating plant installations, the compressors are provided with either adjustable-speed motors or two-speed motors which are used to reduce compressor capacity. When the heat load for the plant is comparatively small, the setting of a switch (provided at the motor controller) is changed from normal, full-speed position to a fractional-speed position (usually one-half speed); the compressor's speed and capacity are correspondingly reduced. The shift from full speed to fractional speed is usually accomplished manually; specific instructions for making this change are included in the instruction book for the plant. Some installations are equipped with a low-pressure switch which shifts the motor from one speed to the other automatically as the compressor-suction pressure varies with changes in the heat load.

Another method of regulating compressor capacity, occasionally employed in Freon–12 plants installed aboard naval vessels, consists of bypassing the vapor pumped by one or more cylinders of a multicylinder compressor back to the suction line, instead of compressing it and discharging it to the condenser. The compressor head of the cylinders to be bypassed is isolated from the head over the other cylinders. A check valve is provided in the normal discharge connection from the head of the cylinders to be bypassed and a bypass line leading to the compressor suction line is installed. A solenoid valve controlled by the compressor suction-pressure switch is installed in this bypass line. When the compressor suction-pressure decreases to a predetermined value, the solenoid valve opens, bypassing the vapor pumped by

the cylinders back to the compressor suction line. The check valve in the normal discharge connection from the head closes, preventing vapor compressed by the working cylinders from backing up through the bypass lines.

Some large Freon–12 compressors are provided with ports in the cylinder walls. These ports are above the top of the piston when it is at the bottom of its stroke; they communicate with the compressor-suction line through port-control valves, which are operated either manually or automatically. Capacity reduction is accomplished by opening the port-control valves; part of the cylinder vapor is thus bypassed before the remainder of the vapor is compressed and discharged to the condenser.

The latest refrigerating and air conditioning compressor units are provided with automatic capacity-control mechanisms. The control mechanism prevents short cycling during periods of light loads; the mechanism also permits the starting of compressors without load. The capacity control automatically cuts cylinders out of operation by means of an oil-pressure operated mechanism. The mechanism holds the suction valve disk open so that no gas can be compressed. The cylinders are unloaded consecutively as the suction pressure is reduced.

Securing The Compressor

If a compressor is to be secured for only a short period, it is not necessary to pump down the system. The compressor however, must be pumped down. To do this, first close the compressor-suction valve slowly, to prevent too rapid a reduction in crankcase pressure. Then allow the compressor to run until it is stopped by the low-pressure control switch; push the STOP button on the motor-control panel. Next, close the compressor-discharge shutoff valve; shut off the water supply to the condensers. Finally, close the main liquid valve after the receiver.

If a refrigeration system is to be secured for an extended period, the system must be pumped down. The pumping-down procedure involves pumping most of the

Freon–12 out of the coils of the evaporator, and storing the refrigerant in the receiver. If the quantity of liquid refrigerant contained in the system is in excess of the capacity of the receiver, the surplus liquid must be drawn off into refrigerant drums. (See Maintenance of Freon–12 Systems, later in this chapter.)

Notes on the Operation of Compressors

A Freon–12 compressor should not remain idle for an extended period of time. When two or more compressors are installed for a particular plant, the compressors should be operated alternately so that the total operating time on each of the compressors is approximately the same. An idle compressor should be operated at least once a week.

Except in an emergency, only one compressor should serve a cooling-coil circuit. When compressors are operated in parallel on a common cooling-coil circuit, lubricating oil may be transferred from one compressor to another. Such transfer of oil may result in serious damage to all compressors on the circuit.

If an emergency requires that two compressors be operated on a common refrigerating load, the compressor-suction line valves should be carefully regulated to ensure that equal quantities of the lubricating oil are returned with the suction vapor to each compressor. The regulation of the amount of lubricating oil returned to each compressor can be determined only by careful observation of the oil level in each crankcase. The proper oil level must be maintained in the crankcase of each compressor under all operating conditions.

MAINTENANCE OF FREON–12 SYSTEMS

As a Machinist's Mate 2, you will do some of the maintenance jobs required to keep a refrigerating plant operating efficiently. In order for you to perform your share of the required maintenance on a refrigerating system, you must be familiar with the proper procedures

for the following jobs: defrosting the cooling coils; opening a charged or functioning system; securing a plant for an extended period; purging a system of non-condensable gases; testing for refrigerant leaks; and cleaning the condenser tubes and the strainers and filters in the lubricating-oil and refrigerant systems.

Defrosting of Cooling Coils

The cooling coils should be defrosted as often as necessary to maintain the effectiveness of the cooling surface. Excessive accumulations of frost on the coils will result in reduced cooling capacity, low compressor-suction pressure, a tendency for the compressor to short cycle, etc. The maximum permissible time interval between defrosting operations depends on many factors, such as refrigerant evaporating temperature, free-moisture content of supplies placed in the refrigerated space, temperature of refrigerated spaces, frequency of opening of cold-storage compartment doors, and atmospheric humidity. In the average cold-storage refrigerating installation, it is good practice to defrost cooling coils before the average frost thickness reaches three-sixteenths inch. This is not a hard and fast rule, however, and in some cases the frost layer may become appreciably thicker without seriously interfering with plant operation; in other cases it may be necessary to defrost more often to maintain satisfactory operation of the plant and proper compartment temperature. Never, however, let more than one-quarter inch of frost accumulate on the evaporator coils.

The most COMMON METHOD OF DEFROSTING a cooling coil in the average Freon-12 refrigerating installation is (1) to shut off the supply of Freon to the coil to be defrosted, by closing the liquid-line stop valve ahead of the expansion valve; and (2) to permit the temperature in the compartment to rise above 32° F., by leaving the entrance door open. The frost melts off the coils or may be easily brushed off. Since the cooling coils are made

of tinned copper or galvanized steel tubing, care should be taken not to damage the evaporator coil if a scraper is used to remove frost.

Many Freon-12 plant installations now in use are provided with HOT-GAS DEFROSTING lines to facilitate defrosting of the meat-room evaporator. The principal advantage of hot-gas defrosting is that the process permits defrosting of the coils, with the plant in operation, without elevating the compartment temperature above 32° F.

A pipe line is led from a point in the compressor-discharge piping to the suction connection from the meat-compartment evaporator. In addition to this hot-gas line, the refrigerant-supply piping to the meat-room cooling coil is provided with a line which connects, just beyond the expansion valves, with the cooling coils of the fruit and vegetable room or those of the butter and egg room. Stop valves are provided in the hot-gas line at the connection to the suction side of the meat-room coil; a manual expansion valve is installed in the auxiliary liquid line.

When it is desired to defrost the coils of the meat room, the normal refrigerant-liquid supply and suction return-line valves of the cooling coils are closed. The valve in the hot-gas supply line is then opened; compressed refrigerant-gas is admitted to the coil. As the frost melts on the exterior coil surfaces, the gas is condensed in the coils. In order to rid the coil of condensed refrigerant, the refrigerant-liquid supply valve to the other coil (for the butter and egg room or the fruit and vegetable room, as the case may be) is closed; and the condensed refrigerant in the meat-room coil is expanded, through the manual expansion valve, into this other cooling coil. Upon completion of the defrosting process, the system is returned to its normal operating condition by closing the auxiliary defrosting valves and opening the valves in the refrigerant-liquid supply lines to the coils and the suction return valve from the de-

frosted coil. Care must be taken that all liquid refrigerant has been discharged from the meat-room coil before the suction-line valve from the compartment is opened. If all the liquid has not been discharged, liquid slugs may be returned to the compressor.

Pumping Down A Refrigerant System

The pumping-down procedure to be followed will depend on the maintenance to be done. In some cases, the necessary maintenance can be performed on the charged system after a part to be repaired or replaced has been isolated. Generally, it is possible to pump down any part of a charged system except the condenser, the liquid receiver, and the compressor-discharge line. In cases where repairs are to be made to a major portion of the system, the refrigerant system must be pumped down to return all refrigerant to the receiver. If repairs are to be made to the receiver, the condenser, or the compressor-discharge line, the entire system must be drained.

PUMPING DOWN PART OF A CHARGED SYSTEM.—Whenever it is necessary to open a charged system in order to make repairs or replacements or to clean strainers, the refrigerant pressure within the part of the system to be opened should be pumped down to a pressure slightly above atmospheric (½ to 5 pounds gage) before any connections are broken. It is generally possible to pump down any part of the system (except the condenser, the liquid receiver, and the compressor discharge line) by proper manipulation of cut-out valves. As a part of the system which contains liquid Freon–12 is pumped down, its temperature will decrease as a result of the evaporation of the liquid refrigerant. When the temperature of such a part of the system begins to rise to normal again, while the low pressure in the part is maintained, it is reasonably certain that all Freon–12 liquid within the part has been evaporated.

If, in the final evacuation of a part of the system, a pressure of less than 0 psig is reached, sufficient refrig-

erant should be immediately bled into the evacuated part of the system to raise the pressure to between ½ and 2 psig. Connections may then be opened; and repairs, replacements of parts, or other necessary service operations may be accomplished.

When a refrigerant system is opened, the free ends of the refrigerant lines should be temporarily plugged in order to prevent the entrance of air and dirt. When the connections are remade, one connection is made tight while the other connection is left loose, temporarily, so that the air or other foreign gases in the section of the system which is serviced can be swept out through the free end as this section of the system is slowly purged with refrigerant-gas bled from the charge in the system. The other connection or connections are then quickly tightened. Refrigerant, oil-charging, gage, and control lines, although generally of small size and short length, should be purged with refrigerant-gas immediately before they are connected to the system. Where connecting lines which have been removed are to be used again, the ends of the lines should be capped to protect the connecting fitting and to ensure that the tube will be clean when it is used again.

PUMPING DOWN A SYSTEM FOR MAJOR REPAIRS.—When repairs are to be made to a major portion of the system or when the system is to be secured for an extended period, the refrigerant system must be pumped down to return all refrigerant to the receiver. Sufficient refrigerant-gas should be retained within the system to create a positive pressure of approximately 2 psig throughout the circuit, except within the compressor-discharge line and the condenser, and between the receiver and the main liquid-line shutoff valve. Close the main liquid-line shutoff valve and the dehydrator-bypass valve, and open the cooling-coil solenoid valves. Allow the compressor to operate on manual control until the suction pressure reaches approximately ½ to 2 pounds; then stop the compressor. Repeat the operation until the liquid

refrigerant in the circuit has evaporated and the suction pressure remains relatively constant at ½ to 5 pounds. During the pump-down period, the evaporation of liquid refrigerant can be traced on the liquid line back to the main liquid shutoff valve by the formation of frost and its subsequent melting as the liquid refrigerant is evaporated and superheated. Open the power-supply switch to the compressor and to the pump motors and solenoid switches; close the compressor suction and discharge shutoff valves. Shut off the water supply to the condenser and drain the condenser water. Where the amount of liquid refrigerant contained in the system is in excess of the capacity of the receiver, the surplus liquid refrigerant must be drawn off into separate refrigerant drums.

To drain the refrigerant charge from the system when it is necessary to make repairs to the condenser, the liquid receiver, or the compressor discharge line, or for any other reason, proceed as follows:

1. Start the compressor and pump down the cooling coil and suction-line pressure, with the liquid-line valve at the receiver outlet closed, to the point at which the low-pressure control switch stops the unit.
2. When the compressor is stopped by the low-pressure cut-out switch, restart the unit manually and continue the pumping-down procedure until the compressor-suction pressure is reduced to about 2 psig.
3. Close the compressor discharge line valve; close all liquid valves at the cooling coils.
4. Connect an empty Freon–12 service drum to the refrigerant drain valve. (Before connecting the drum to the Freon–12 system, immerse it in an ice water bath to cool the drum thoroughly and thus permit rapid draining of the refrigerant into the drum. The colder the drum, the less Freon–12 it will allow to remain in the system.) Always use a clean Freon–12 service drum containing no air or

water so that the drained Freon–12 may be kept in suitable condition for future use.

5. Purge the air out of the line connecting the drain valve and the drum by leaving the connection at the drum valve open and as you slowly flush refrigerant through the line and out at the connection; then close the connection. The Freon–12 may now be drained into the cooled drum by opening the drain valve and the service drum valve.
6. When the service drum is full, close the drain valve and permit the Freon–12 liquid in the drain line to evaporate; then close the service drum valve and disconnect the drum from the system.
7. Weigh the drum to be certain that it has not been overcharged. The net and gross weights are stamped on the drum. (These weights include that of the cast iron protector cap which fits over the cylinder valve.)

CAUTION: Never fill a service drum beyond its rated capacity; drainage may result from hydraulic pressure upon rise in temperature.

8. Discharge the Freon–12 vapor, which remains in the condenser and receiver to the atmosphere through the purge valve.

Testing for Refrigerant Leaks

Refrigerant leaks mean the loss of refrigerating effect. Various tests are used to determine the existence of leaks in refrigerant systems. Pressure tests are used after the installation of a system and after extensive repairs or replacement of parts have been made. Pressure tests are made before the system is charged with Freon–12. Charged systems are tested for leakage either with a halide leak-detector or with soapsuds; which of the two methods is to be used will depend largely upon the size of the leak, and upon the type of space in which the test is to be performed.

As an MM2, you will be required to know how to use

the detector and how to use soapsuds to check for Freon-12 leakage. In addition to those tests for leaks which are made at periodic intervals, tests should be made before the compressors are started and at any other time that a shortage of refrigerant in the system is suspected. Unusual operating conditions which indicate a shortage of refrigerant in the system are:

1. High suction-line temperatures.
2. Relatively high crankcase and cylinder temperatures.
3. Excessively high refrigerant temperature in the liquid line.
4. Bubbles in the refrigerant sight-flow indicator.
5. Liquid refrigerant carrying partially through the coil, with considerable superheat at the thermal element.
6. Compressor running continuously.
7. Excessive oil seepage at shaft seal connection.
8. Oil seepage at refrigerant-system piping and compressor connections.

A shortage of refrigerant in the system nearly always indicates the presence of leaks. When a shortage of refrigerant is found the entire system should, therefore, be tested for leaks by one of the following methods.

USE OF HALIDE LEAK-DETECTOR.—The most positive method of detecting leaks in a Freon-12 system is the use of the halide leak-detector. Such a detector consists essentially of a torch burner, a copper reactor plate, and an exploring hose. (See fig. 5-1.)

Most detectors use either acetylene gas or alcohol as a fuel. Pressure for detectors which use alcohol is supplied by a pump. If a pump-pressure type of alcohol-burning detector is used, be sure that the air pumped into the fuel tank is pure.

Atmosphere suspected of containing Freon-12 vapor is drawn, by injector action, through the exploring hose into the torch burner of the detector. Here the air passes over the copper reactor plate, which is heated to in-

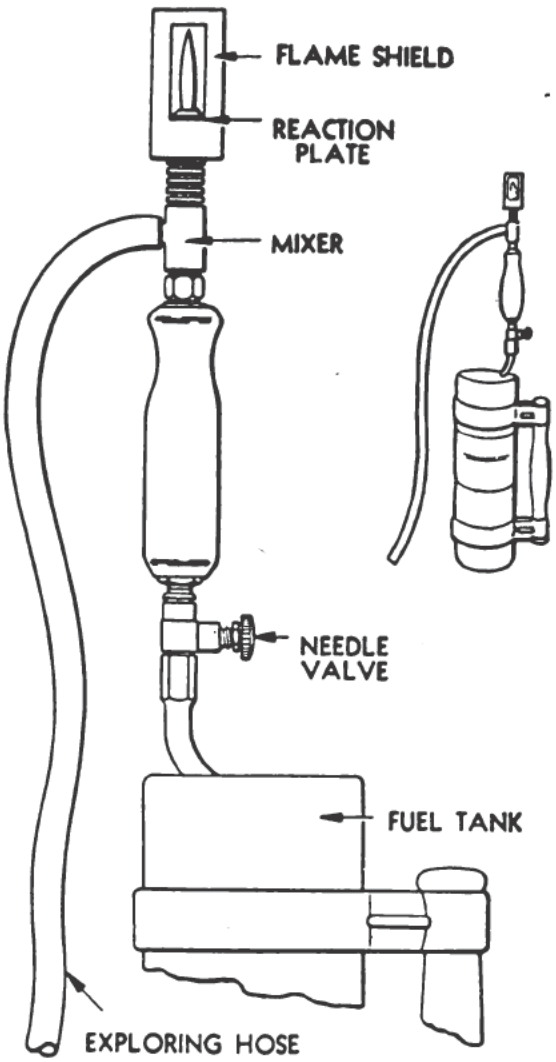


Figure 5–1.—Halide leak-detector.

candescence. If there is a minute trace of Freon–12 present, the color of the torch flame will change from a blue (neutral) to green as the Freon–12 comes in contact with the reactor plate. The shade of green will depend upon the relative amount of Freon–12 present; a pale green indicates small concentrations and a darker green shows heavier concentrations. Excessive quantities of Freon–12 will cause the flame to burn with a vivid purple color. Extreme concentrations of Freon–12 may extinguish the flame by crowding out the oxygen available from the air.

When a leak detector is used, best results are obtained if the following precautions are observed:

1. Be sure that the reactor plate is properly in place.
2. Adjust the flame so that it does not extend beyond the end of the burner. (A small flame is much more sensitive than a large flame. If difficulty is experienced in lighting the torch when it is adjusted to produce the necessary small flame, block the end of the exploring hose until the fuel ignites; then gradually open the hose.)
3. Clean out the exploring tube if the flame continues to have a white or yellow color. (A white or yellow flame indicates that the exploring tube is partially blocked with dirt.)
4. Check to see that air is being drawn into the exploring tube; this check can be made, from time to time, by holding the end of the tube to your ear.
5. Hold the end of the exploring tube close to the joint being tested; this prevents dilution of the sample by stray air currents.
6. Move the end of the exploring hose tube slowly and completely around each joint being tested. (Leak testing cannot be safely hurried. There is a definite time lag between the moment when air enters the exploring tube and the moment it reaches the reactor plate; permit sufficient time for the sample to reach the reactor plate.)
7. If a greenish flame is noted at any time, repeat the test in the same vicinity until the source of the Freon–12 is determined. (It may be necessary to use soapsuds to find the exact location of the leak.)

USE OF SOAPSUDS.—A halide torch is so sensitive that it is useless if the atmosphere is contaminated by excessive leakage of Freon–12. This is most likely to happen in a small or poorly ventilated compartment. In such a case, the soapsuds test must be used.

Prepare the soap-and-water solution so that it has the consistency of liquid hand soap, and will work up a lather

on a brush. (The lather will remain wet for a longer period if a few drops of glycerin are added to the solution.)

Apply the lather all the way around the joint; then look carefully for bubbles. If a joint is so located that a part of it is not visible, use a small mirror when inspecting it. Remember that it sometimes takes a minute or more for bubbles to appear, if the leak is small. Doubtful spots should be lathered and examined a second time.

Always follow a definite procedure in testing for refrigerant leaks, so that no joints will be missed. Even the smallest leak is not to be considered negligible. However insignificant the leak may seem, it eventually empties the system of its charge to the point of faulty plant operation. Because Freon–12 is practically odorless, the first indication that leakage exists is the loss of refrigerating effect. The extra time spent in testing all joints will be justified. A refrigerant system should never be recharged until all leaks are discovered and definitely repaired.

Never use oil to test for Freon–12 leaks. Oil is not reliable because of the capacity of the oil for absorbing Freon–12. If a small leak should exist where oil has been applied, the Freon–12 will be absorbed by the oil and will show no indication (bubbles) of the leak until the oil is saturated with Freon–12. Furthermore, if a halide torch is used to test a joint that has been tested previously with oil, the torch will give a false indication because of the Freon–12 released from the oil.

Air and Noncondensable Gases In a Refrigerant System

It is essential that every reasonable precaution be taken to keep air and noncondensable gases out of a refrigerant system. When air enters the system the condenser must be purged, with a resultant loss of refrigerant. Atmospheric air always contains some moisture, which will enter the system when air does. A refrigerant system must be kept as moisture-free as possible to

eliminate such troubles as the freezing of water at the expansion valves, internal oxidation or corrosion of parts, and emulsification or sludging of lubricating oils.

Air and noncondensable gases in a refrigerant system are pumped through the system and are discharged by the compressor into the condenser. These gases are trapped in the condenser by the liquid seal maintained over the receiver outlet. These gases are, in general, lighter than the relatively dense Freon-12 vapor; they tend to collect, therefore, in the upper part of the condenser when the compressor is stopped. The purge valve for discharging these gases to the atmosphere is located either in the upper part of the condenser shell or in the compressor discharge line above the condenser. While the compressor is in operation, any noncondensable gases in the system are thoroughly mixed with the Freon-12 vapor. This mixing is caused by the turbulence produced by the rapidly pulsating discharge of refrigerant into the condenser. Therefore, it is not advisable to attempt to purge noncondensable gases from the system while the compressor is in operation. Noncondensable gases in a condenser cause excessive condensing pressures with a resultant loss in plant efficiency.

TESTING A REFRIGERANT SYSTEM FOR NONCONDENSABLE GASES.—The best time to check a Freon-12 system for noncondensable gases is immediately before the compressor starts after a shutdown period. When a condenser is to be checked for noncondensable gases, it is essential that the gages and thermometers used be accurate and that the system have sufficient refrigerant charge so that the liquid refrigerant present in the receiver will seal the liquid-line connection.

The following procedure should be followed when checking a refrigerant system for noncondensable gases:

1. Close the liquid-line valve.
2. Shut off the compressor and close the suction-line valves.

3. Determine the actual condensing temperature of the refrigerant.

   A service gage should be installed in the compressor-discharge connection if a discharge-pressure gage is not already provided. An approximation of the actual condensing temperature of the refrigerant will be reached when no further decrease is noted in the discharge pressure. (On water-cooled condensers, the reduction in pressure can be accelerated by permitting circulation of condenser water until discharge pressure is reduced.) The thermometer provided on most vessels in the liquid line at the receiver will then indicate the actual condensing temperature. If a thermometer is not installed in an air-cooled condenser application, one should be placed near the condenser to record the ambient temperature at that location. When the temperature of an air-cooled condenser has dropped to the ambient temperature, the reading of the thermometer will approximate the actual condensing temperature.
4. On the compound pressure gage, read the condensing temperature which corresponds to the condensing pressure registered by the high-pressure gage; the temperature indicated on the temperature scale is the condensing temperature of pure Freon–12 at the pressure indicated by the gage. (See *Machinist's Mate 3,* NavPers 10522.)
5. Subtract the existing condensing temperature from the condensing temperature of pure Freon–12 at the existing condenser-pressure. If the difference between these two temperatures is more than 5° F., it will be necessary to purge the condenser of noncondensable gases.

PURGING A REFRIGERANT SYSTEM OF NONCONDENSABLE GASES.—If the above test indicates the need for purging, slowly release the noncondensable gases. When a purge

valve is not provided, purge the gases by opening the discharge-pressure gage connection.

The proportion of Freon–12 gas that will mix with the noncondensable gases and escape while the condenser is being purged will depend upon the rate of purging and upon the concentration of the noncondensable gases in the condenser. No practical test is available aboard ship to determine definitely when an excessively high proportion of Freon–12 gas is being purged with the noncondensable gases. To keep the Freon–12 loss to a minimum when the condenser is being purged, purge slowly; and frequently check the condenser for noncondensable gases. Freon–12 is odorless in concentrations of less than 20 percent by volume in air; in heavier concentrations, however, it resembles carbon tetrachloride in odor. If you can get close to the purge-valve discharge, you may be able to determine by the odor of the purged gases when purging should be discontinued and when the check for noncondensable gases should be repeated. Protect your eyes with goggles when you are checking the odor of purged gases.

Cleaning Procedures

If a refrigerating plant is to operate efficiently, the circuits through which the refrigerant, the lubricating oil, and the cooling water flow must be kept clean. Keeping the condensers and the various filters and strainers clean will be part of your responsibility.

CLEANING OF WATER-COOLED CONDENSERS.—Freon–12 condensers should be inspected as often as practicable to determine whether or not cleaning is required. To clean a water-cooled condenser, it is necessary first to drain the cooling water from the condenser, and then to remove the water connections and water chests. As the water chests are removed, be careful not to damage the gaskets between the tube sheet and the water side of the water chest.

The tubes of a Freon–12 condenser can be cleaned by

pushing an air lance through each tube, washing the tube sheets clean, and removing any foreign matter that may be in the water chests. In cases of severe fouling, a water lance should be used instead of an air lance. In cases of extreme fouling, a rotating-bristle brush may be run through each tube; or soft rubber plugs (if available) may be driven through the tubes by an air or water gun. After brush or plug cleaning of the tubes, a water lance should be used to remove any foreign material remaining in the tubes of the condenser.

Abrasive tools which would scratch or mar the condenser tubes must not be used. Any scratch on the surface of a tube may lead to tube failure from corrosion. Air and water lances and other cleaning equipment must be used carefully to avoid damaging the tubes and causing subsequent tube failures.

Zinc protectors are installed in the water boxes of Freon–12 condensers to minimize electrolytic corrosion of the condenser parts which are in contact with sea water. Zinc protectors should be inspected at least once a month, and more often if necessary; they should then be thoroughly scaled to ensure that active metallic zinc surface is exposed to the sea water at all times. The zinc surface which affords proper protection to the parts of the condenser in contact with sea water is quickly deteriorated. Zincs which are more than one-half deteriorated should be replaced.

CLEANING OF AIR-COOLED CONDENSERS.—The tubes and fins of air-cooled condensers should be kept free of dirt, lint, and any other obstruction to heat flow or air circulation. The finned surface should be brushed clean with a stiff-bristle brush as often as necessary to prevent accumulation of foreign matter. When condensers are exposed or accessible to salt spray or rain, care should be taken to minimize corrosion of their exterior surfaces. The finned surface of an air-cooled condenser is usually coated with solder; it should, therefore, never be painted, but may be retinned if necessary.

CLEANING OF REFRIGERANT STRAINERS.—The strainers and filters in the refrigerant system should be cleaned after the first few hours of operation to remove the foreign matter loosened from the system by the solvent action of the Freon-12 and circulated through the refrigerant lines. Another cleaning is usually necessary after the first few days of operation. The strainers should be inspected frequently during the early service life of the plant and cleaned when necessary. The interval of time between periodic cleanings is usually based on service experience.

The SUCTION-LINE STRAINER at the compressor functions to prevent scale or other foreign matter from entering the compressor. To clean the strainer screen, proceed as follows:

1. Pump out the compressor, following the same procedure used when securing the plant for major repairs or when shutting the plant down for an extended period of time.
2. Mark the strainer-body cover so that it can be replaced in its original position. The gasket should also be replaced in its original position.

(CAUTION: Before the strainer is opened, be sure the suction-pressure gage shows a pressure slightly above atmospheric. Use accurate gages.)

3. Remove the strainer-body cover and withdraw the strainer; replace the cover on the strainer body immediately to prevent foreign matter and atmospheric moisture from entering the system.
4. Clean the strainer and spring by washing them in an approved solvent; dry them with compressed air.
5. Clean the strainer seat inside the strainer body; be careful to wipe out any particles that may drop down into the strainer body. (Use only chamois or lint-free cloth.) If the strainer seat is dirty, the

screen will not seat properly and dirt may pass into the compressor.

6. Reassemble the strainer in the body, with the spring in place.
7. Check the condition of the cover gasket; replace the gasket, if necessary.
8. Secure the strainer cover to the body; tighten the capscrews evenly.

The procedure to be followed when cleaning the LIQUID STRAINERS is similar to that used when cleaning the suction-line strainers, except that the pumping-out process applies only to the liquid strainer section, which is isolated.

CLEANING OF LUBRICATING-OIL FILTERS AND STRAINERS.—A Freon–12 compressor designed for forced-feed lubrication is provided with a lubricating-oil strainer in the suction line of the lubricating-oil pump; an oil filter is usually provided in the pump-discharge line. A gradual and progressive decrease in lubricating-oil pressure indicates that these units require cleaning.

The method of cleaning these filters and strainers is similar to the procedure for cleaning the suction-line strainer. When the strainers and filters are to be cleaned, the lubricating oil in the crankcase should be drained from the compressor unit; the drained lubricant should be replaced with a fresh charge after the strainers or filters have been cleaned. When the lubricating-oil system is reassembled, the working lubricating-oil pressure should be adjusted to the proper point by adjustment of the oil-pressure regulating valve.

REFRIGERANTS

Most refrigerating plants installed aboard naval vessels use Freon–12 as a refrigerant; a few of the self-contained units may use Freon–22 and centrifugal air conditioning systems may use Freon–11. Refrigerating equipment is fundamentally the same, in principle, regardless of the refrigerant used. In operating a refrig-

erating machine, however, it is essential that none but the gas for which the particular machine is designed be introduced into the refrigerant system. You should familiarize yourself with the various refrigerants in use, so that serious error may be avoided.

Characteristics of Refrigerants

A liquid has different boiling temperatures at different pressures under which it is confined. The boiling point at any pressure is also the condensation point at that pressure. This temperature-pressure relation must be determined experimentally for each liquid. Water boils at 212° F. at atmospheric pressure (zero psi gage); at 100° F. at 28 inches of vacuum; and at 338° F at 100 psi gage pressure, etc. At atmospheric pressure, the boiling points of the refrigerants commonly used in refrigerating plants installed on naval vessels are —21° F., —41° F., and +74° F. for Freon-12, Freon-22, and Freon-11, respectively. Because of these relatively low boiling points, the refrigerants named do not exist as liquids at ordinary temperatures and pressures, except Freon-11 which will exist as a liquid below 74° F. Gaseous refrigerants can be changed to liquids by confining them under pressure, cooling the vapor to the boiling (condensing) point for that pressure, and then removing the latent heat of condensation.

FREON 12 (CCl_2F_2).—Pure Freon-12 is colorless. In concentrations of less than 20 percent by volume in air, Freon is odorless; in higher concentrations, its odor resembles that of carbon tetrachloride. It has a boiling point of —21° F. at atmospheric pressure. At ordinary temperatures Freon-12 is a liquid when under a pressure of about 70 to 75 pounds per square inch gage.

Mixtures of Freon-12 vapor and air, in all proportions, are nonirritating to the eyes, nose, throat, and lungs. The refrigerant will not contaminate or poison foods or other supplies with which it may come in contact. The vapor is nonpoisonous; it will not support respiration, however,

and it produces mild anesthesia when it is inhaled in sufficient quantities. In view of its low boiling point at atmospheric pressure, care must be taken to prevent liquid Freon–12 from coming in contact with the eyes; the liquid will freeze the tissues of the eyes. Always wear goggles if you are to be exposed to Freon.

Freon in either a liquid or vapor state is noninflammable and nonexplosive. Freon will not corrode the metals commonly used in refrigerating systems.

The only hazard which may be introduced through the use of Freon–12 as a refrigerant is the very remote health hazard which may be presented should leakage of a large amount of the vapor come in direct contact with an open flame of high temperature (about 1,000° F.) and be decomposed. In order to be a health hazard, the leakage of Freon must be within a confined and poorly ventilated space and the vapor must come in direct contact with a high temperature flame. When these conditions exist, however, the products of decomposition are pungent and irritating, rendering them noticeable even when they are present only in minute quantities; ample warning is available before concentrations dangerous to health are reached.

Freon–12 is a stable compound capable of undergoing without decomposition the physical changes required of it in refrigeration service. It is an excellent solvent and has the ability to loosen and remove all particles of dirt, scale, and oil with which it comes in contact within a refrigerating system.

Freon–22 ($CHClF_2$) and Freon–11 (CCl_2F) are colorless, nonexplosive, nonpoisonous gases with properties similar to those of Freon–12.

Identification of Refrigerant Gases

There are a few refrigerants that have a pronounced odor that is easily detected. The Freon group, however, has practically no odor and the Freons are essentially harmless.

There is no simple chemical test that can be made to identify Freon–12, Freon–22, or Freon–11, since they are stable and inert. Soap bubbles blown with these refrigerants are 3 to 5 times heavier than air. When a lighted match is applied to one of these bubbles the flame tends to be extinguished; the Freons have the same flame-extinguishing properties as carbon tetrachloride.

Identification of Refrigerant Cylinders

The cylinders in which refrigerants are supplied are identified by a color code. (The standard arrangement of the colors used on gas cylinders and the identification markings on such cylinders are described and illustrated in *Machinist's Mate 3*, NavPers 10522). This color code is subject to revision; therefore, it is advisable to check the Military Standards for the code currently in use. According to MIL–STDC–101A, March 16, 1954, the color code for refrigerant cylinders of Freon–12, Freon–22 and Freon–11 is ORANGE. The entire cylinder (top, bands B and C, and body) is painted.

In addition to the color code, the following means of identifying the contents of gas cylinders are provided to ensure positive identification:

1. The name of the gas is stenciled longitudinally at two diametrically opposite points on the cylinder.
2. Two decalcomanias bearing the name of the gas are attached to the shoulder of the cylinder 90° from the points where the name is stenciled.
3. The name of the gas is indented into the cylinder valve.

When you are working with the Freon refrigerants, color alone is not positive identification of the gas contained in a cylinder. Check ALL identification marks on the cylinder.

SAFETY PRECAUTIONS

Certain precautions related to refrigerants and refrigeration equipment have been emphasized in the Navy

training course, *Machinist's Mate 3,* NavPers 10522. Additional precautions have been given in this chapter. You should review all these safety precautions frequently and keep them in mind constantly when you are working with refrigerant gases and refrigeration equipment.

QUIZ

1. Are the stop valves in the condenser circulating-water lines open or closed when the compressor of a Freon–12 system is started?
2. In what position is the selector switch when a refrigerant compressor is ready to be started?
3. When a refrigerating system is being placed in operation, why should the compressor be started and stopped several times?
4. What determines the rate at which the suction valve is opened, after the compressor is operating?
5. How is manual control of the condenser circulating-water flow accomplished?
6. What should be done if a refrigerant compressor becomes overloaded, the overload trip fails to function, and overheating occurs?
7. Give two methods by which the tendency of a compressor to short cycle may be decreased.
8. Is parallel operation or is alternating operation usually employed for a Freon refrigeration installation with two compressors?
9. What is the maximum thickness of frost which may be allowed to accumulate on evaporator coils before defrosting is necessary?
10. Give the two principal steps in the most common method of defrosting a cooling coil.
11. When a cooling coil is being defrosted by the common method, what is done to facilitate increasing the compartment temperature?
12. What is the principal advantage of hot-gas defrosting?
13. After a cooling coil has been defrosted by the hot-gas process, why is it necessary to discharge all refrigerant liquid from the defrosted coil before the suction-line valve is opened?

14. What must be done if, in pumping down a Freon refrigerating system, a pressure below 0 psi is accidentally reached?

15. When a refrigerating system is being pumped down to return all refrigerant to the receiver, what indicates that the liquid refrigerant in the circuit has evaporated?

16. When the charge is to be drained from the liquid receiver, what is done to make rapid draining possible?

17. How is air purged from the line which connects the drain valve of a receiver and the service drum?

18. What is done to determine whether or not a refrigerant service drum has been overcharged?

19. Give two methods by which a charged refrigerating system may be tested for leaks.

20. When a halide leak-detector is used to test for Freon–12 leaks, what color is the flame when no leak is present? When a Freon leak is present?

21. When a halide leak-detector is being used to test for Freon leaks, why is it necessary to move the end of the exploring tube slowly?

22. What should be used to locate a leak in a refrigerating system if the surrounding atmosphere is contaminated with an excessive concentration of Freon?

23. What is the first indication of Freon leakage in a refrigerating system?

24. When should Freon condensers be purged of air and other noncondensable gases?

25. How are noncondensable gases purged when no purge valve is provided on a condenser?

26. List the equipment which may be used to clean the tubes of a water-cooled Freon–12 condenser.

27. What determines when the zincs in the cooling-water circuit of a Freon–12 condenser should be replaced?

28. What is used to coat the finned surfaces of an air-cooled condenser?

29. What must not be used to recoat the finned surfaces of an air-cooled condenser?

30. What usually determines the time interval between the periodic cleaning of the strainers and filters in a refrigerant system?

31. When the screen in the suction-line strainer requires cleaning, is it necessary to pump down the system or just the strainer section?

32. What indicates that the filters and strainers in the lubricating-oil system of a Freon–12 compressor need cleaning?

33. Name some properties of the refrigerants in the Freon group.

34. Which of the following would be the most reliable in identifying the refrigerants used in naval installations? (a) Odor. (b) Color. (c) Boiling point.

35. When you are working with refrigerants of different types, what must be done to ensure positive identification of the gas contained in a particular cylinder?

CHAPTER 6

STEAM-OPERATED DISTILLING UNITS

As a Fireman, you were required to know the function of shipboard distilling plants and to be able to locate and identify the units of such plants. To qualify as a Machinist's Mate 3, you had to learn the principles of operation of submerged-tube distilling units, and you had to be able to operate and to perform certain maintenance jobs on units of that type. As a Machinist's Mate 2, you will be held responsible for additional maintenance jobs on distilling units of the submerged-tube type. In addition, you should be familiar with new types of distilling units now being installed on some modern ships; you may be assigned to operate and maintain units of new design.

As pointed out in *Machinist's Mate 3,* NavPers 10522, low-pressure distilling plants now being installed on some new ships in the Navy include units of the vertical-basket and the flash types. These units differ in design from the more common low-pressure submerged-tube units. Since vertical-basket and flash type units are relatively new, keep in mind that service experience may reveal the need for modifications of equipment and changes in operating and maintenance schedules; be sure to check the most recent manufacturer's technical manual when you are assigned to operate and maintain a distilling unit of new design.

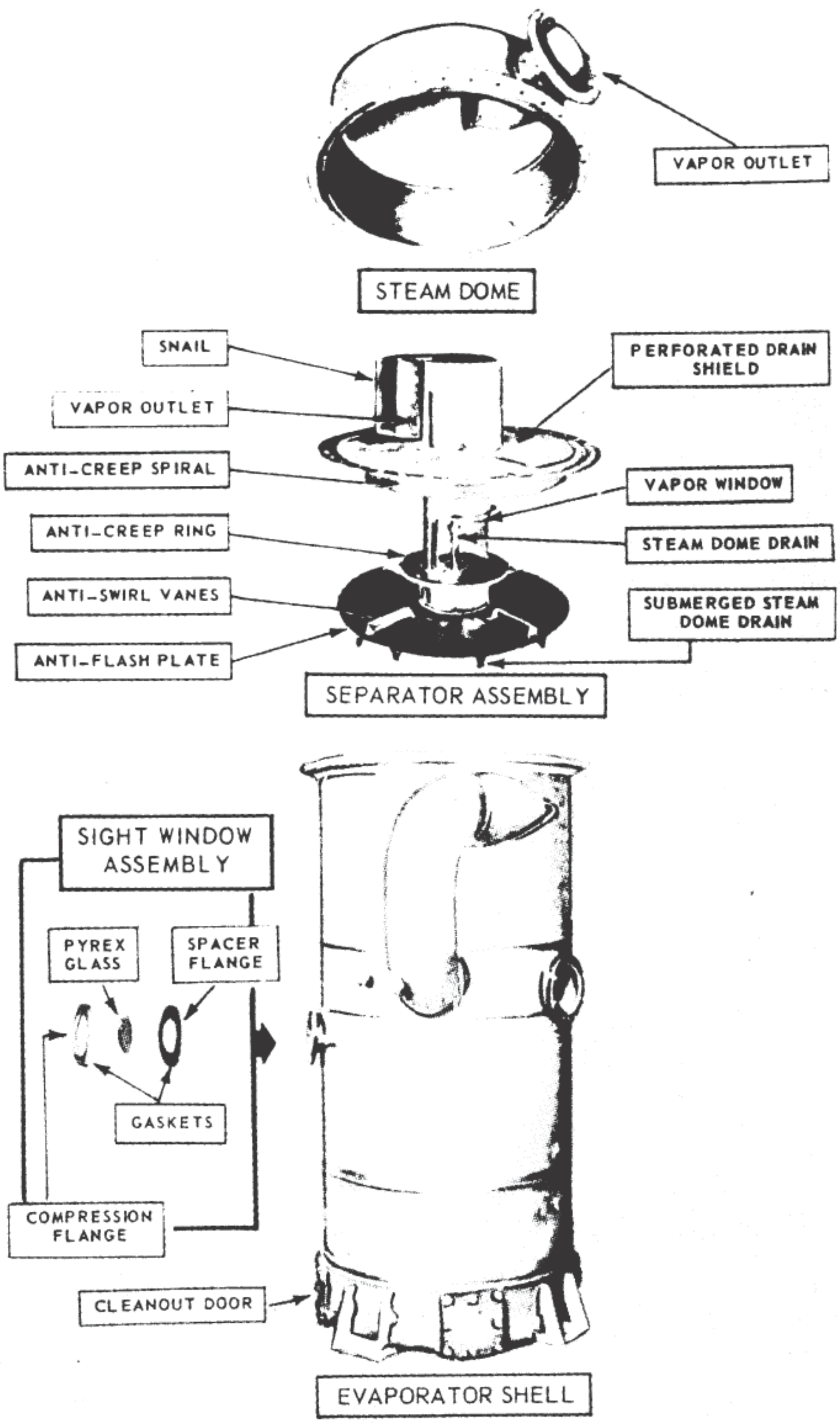


Figure 6–1A.—Vertical-basket unit—steam dome and evaporator shell.

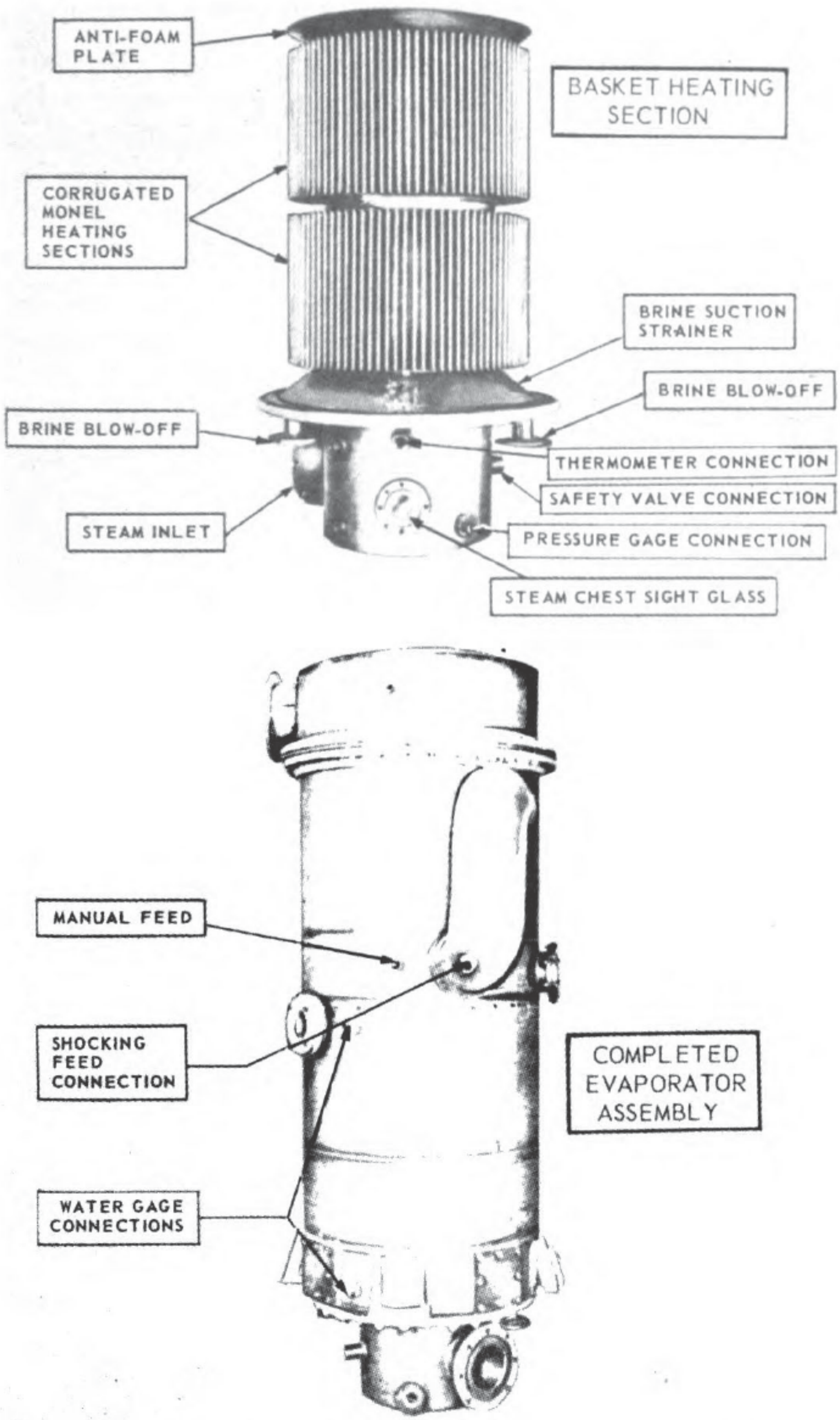


Figure 6–1B.—Vertical-basket evaporator—basket heating section and complete evaporator assembly.

VERTICAL-BASKET DISTILLING UNITS

Distilling units of the vertical-basket type operate on the same principle as the more common submerged-tube units. Except for the evaporators, the principal components of the two types of units are basically the same. Since the parts and the principles of operation of the submerged-tube unit are described in *Machinist's Mate 3*, NavPers 10522, only the evaporator and the details of the various flow circuits of the vertical-basket unit are described in this course.

The 2W–112D double-effect distilling unit is considered in this section. Designed and manufactured by the Maxim Silencer Company, the unit operates on low-pressure steam and has a capacity (under normal operating conditions) of 10,000 gallons per day.

Vertical-Basket Evaporators

The evaporator for each effect of the 2W–112D unit consists principally of a steam dome, a separator assembly, a heating section, and an evaporator shell. The heating section consists of a deeply corrugated vertical cylindrical basket. The evaporators of the first and second effects are identical and are, therefore, interchangeable, The principal components of a vertical-basket type evaporator are shown in figures 6–1A and 6–1B.

Flow Circuits of a Vertical-Basket Distilling Unit

The flow circuits of a vertical-basket distilling unit are illustrated schematically in figures 6–2A, 6–2B, and 6–2C. Refer to these figures as you study about the flow circuits of the unit.

STEAM.—Heating steam from the ship's auxiliary exhaust main is fed through a pressure-control valve to the steam chest of the first effect. The pressure-control valve is set to maintain a constant steam-supply pressure; it should be set for 5 psig steam on the upstream side of the orifice plate for rated output, and lower for

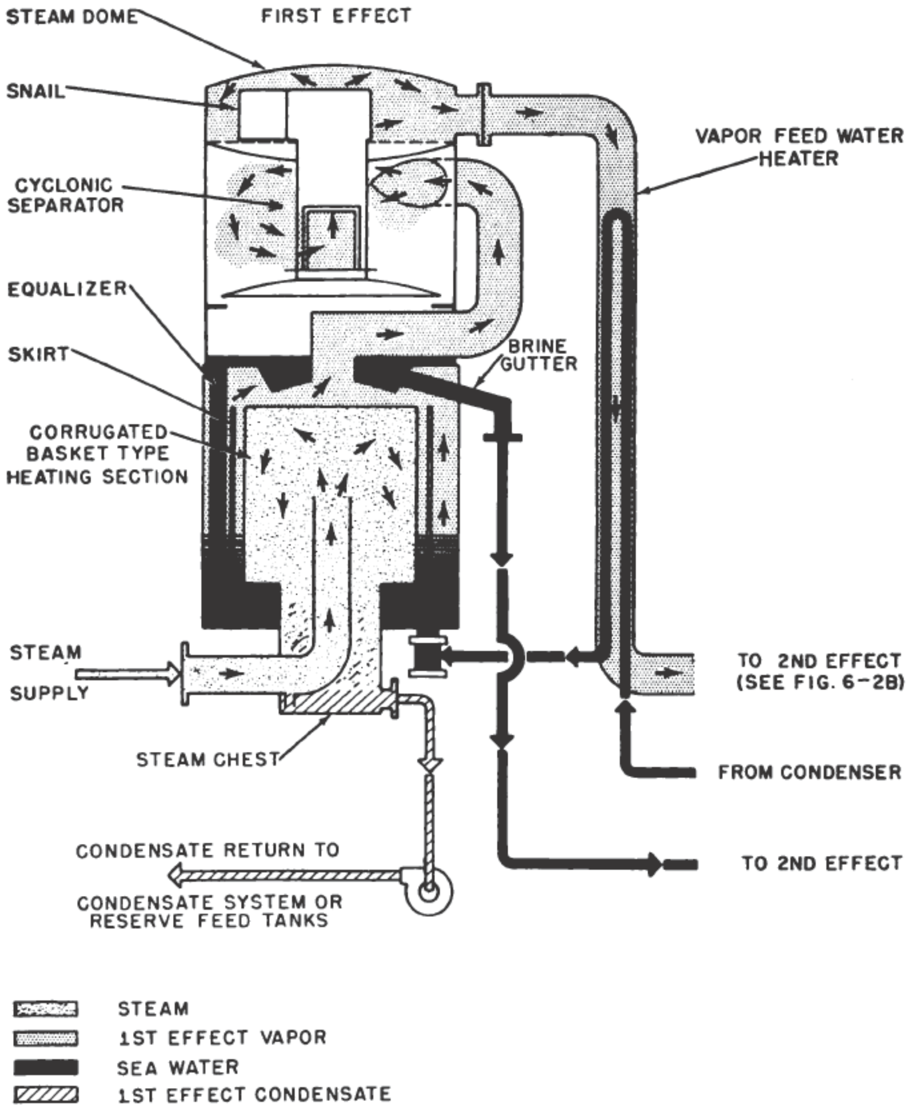


Figure 6–2A.—Flow circuits of a vertical-basket unit—first-stage section.

reduced output. The heating steam is condensed within the corrugated basket; the condensate is returned to the ship's condensate system or reserve feed tanks by the first-effect drain pump. (See fig. 6–2A.)

A steady water level is maintained in the suction line of the first-effect drain pump by the drain controller; this ensures a positive submergence head for the pump. If the first-effect drain pump fails, the evaporator can be kept in operation by bypassing the drain controller and manually controlling the condensate discharge to the

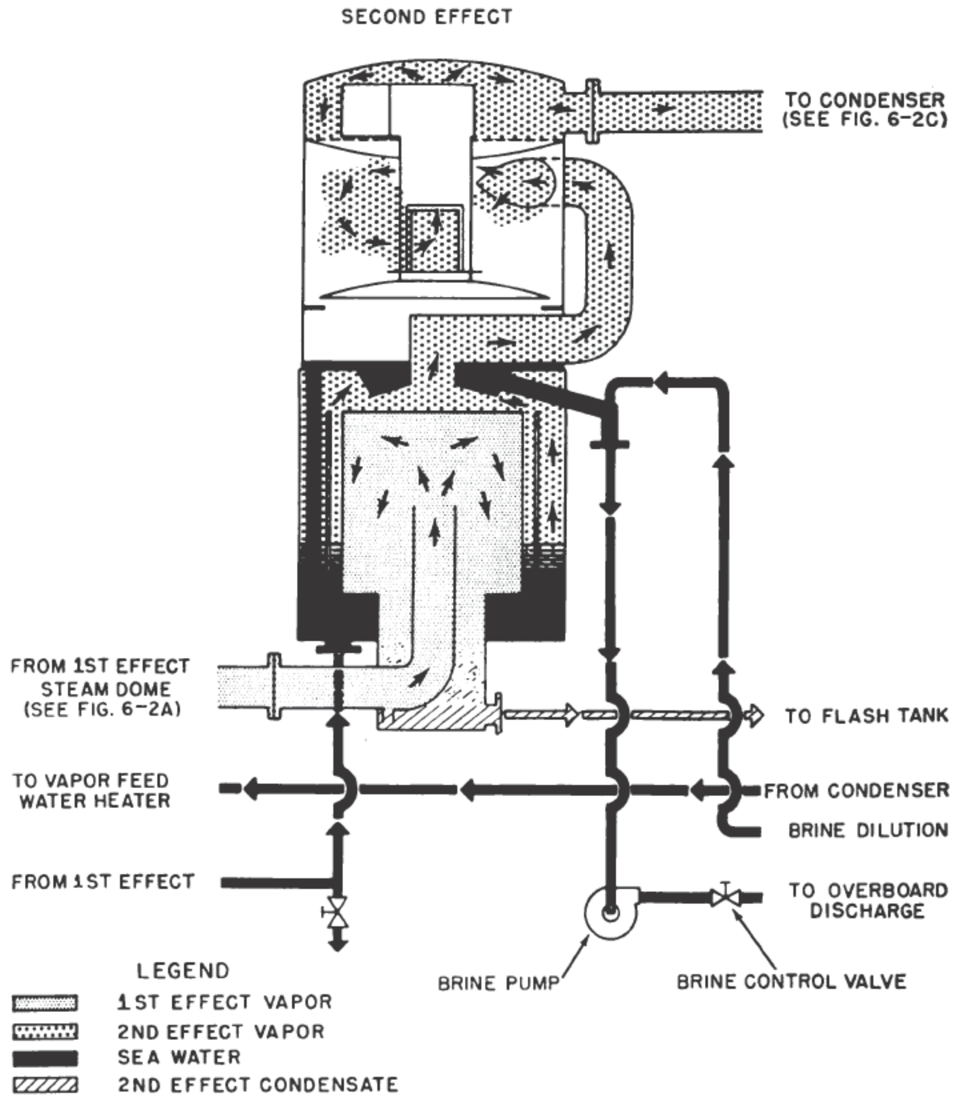


Figure 6–2B.—Flow circuits of a vertical-basket unit—second-stage section.

low-pressure drain mains; at least 1 psig pressure in the steam chest is required, under these conditions, to drain the condensate.

FEED.—Sea-water feed is taken from a sea chest, through a strainer, by the sea-water circulating water pump, and is discharged through the distillate cooler. (The incoming feed serves to cool the distillate from the distiller condenser to within a few degrees of the temperature of the feed.) The sea water then passes through the distiller condenser; the major portion (about 75%)

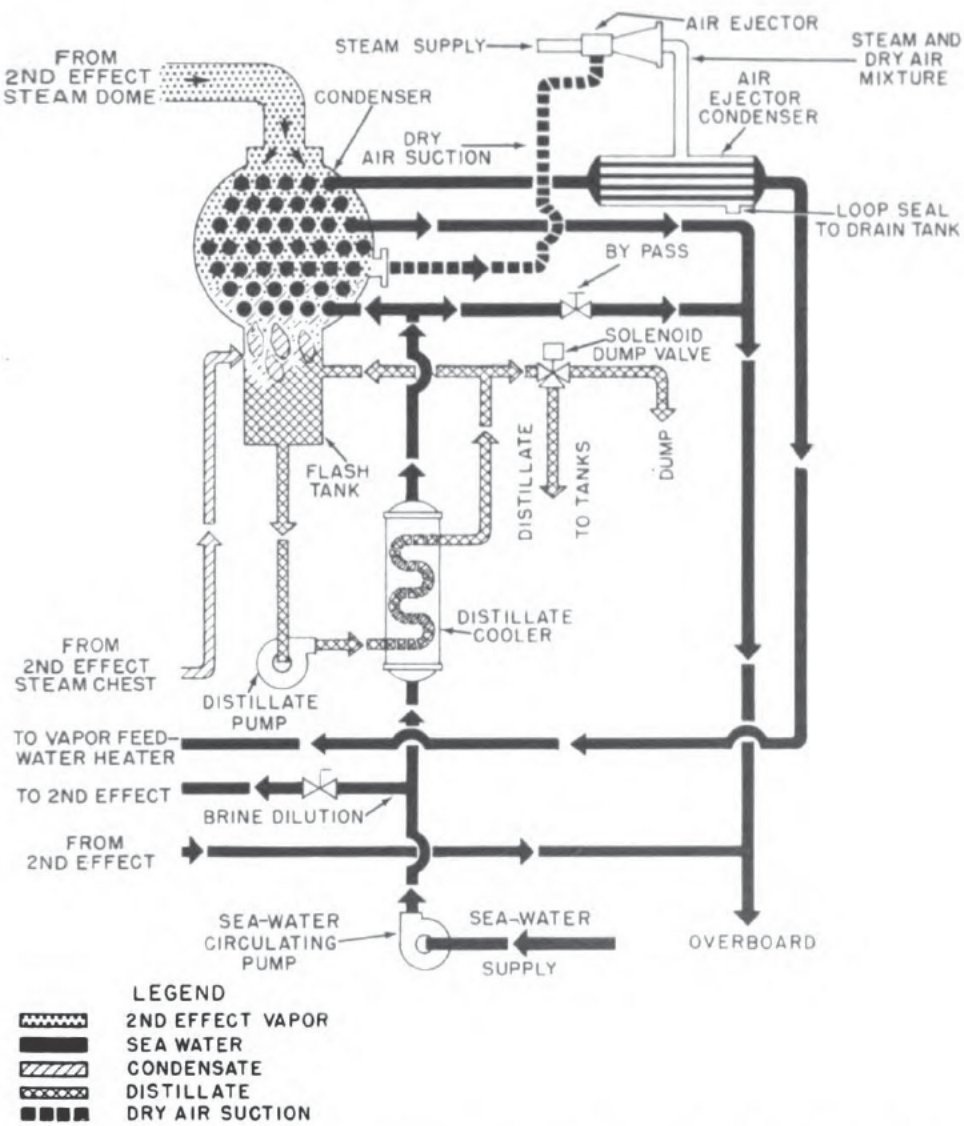


Figure 6–2C.—Flow circuits of a vertical-basket unit—condenser section.

goes through the eductor, combines with the brine (from the second effect), and is discharged overboard. (See fig. 6–2C.)

The feed remaining in the condenser is directed through the after condenser and the vapor feed-water heater to the first effect, where it surrounds the basket. Violent boiling takes place and vapor forms within the first effect. The remaining brine serves as feed for the second effect. (Earlier models were equipped with a

branch from the feed line, which lead from the heating section of the distiller condenser to a connection on the bottom of the second effect; as a result, the second effect was supplied with brine from the first effect, and heated sea water from the heating section of the distiller condenser as feed.) In current models, all feed enters the first effect (figs. 6–2A and 6–2B).

The brine from the second effect is removed by the brine overboard-discharge pump; it is discharged overboard, through the eductor and control valve, after it has been combined (in the eductor) with the sea-water overboard discharge from the distiller condenser (figs. 6–2B and 6–2C).

VAPOR.—The vapor which forms as a result of the boiling of the feed in the first effect passes through the uptake pipe and enters the cyclonic separator above the evaporation section. Most liquid particles which carry over with the vapor are removed by centrifugal force within the first-effect separator. The first-effect vapor passes from the steam dome, through the vapor feedwater heater, to the steam chest and the evaporator basket of the second effect. Some of the vapor, in passing from the first effect to the second effect, condenses as it heats the feed water passing through the vapor feedwater heater. The major portion of the first-effect vapor, however, enters the second-effect steam chest and condenses as it heats the brine in the second effect (figs. 6–2A and 6–2B).

The vapor resulting from the boiling of the brine in the second effect passes through the second-effect uptake into the second-effect separator, where centrifugal force is utilized to remove water particles from the second-effect vapor. (Liquid particles from both stages drain downward and become part of the brine drains.) This two-stage separation results in distillate with less than 0.065 epm chloride, under normal operating conditions. From the second-stage separator, the vapor passes, through the steam dome, to the distiller condenser, where

the vapor is condensed as it is cooled by the incoming feed (figs. 6–2B and 6–2C).

DISTILLATE.—The condensate formed in the second-effect steam chest passes, through a loop seal, to the flash tank of the distiller condenser, under the pressure differential existing between the second-effect steam chest and the flash tank. The loop seal permits only condensate to pass.

The vapor from the second-effect steam dome condenses in the distiller condenser and collects in the flash tank at the bottom of the distiller condenser. The distillate (combined condensate drains from the distiller condenser and the second-effect steam chest) is removed from the flash tank by the distillate pump and is discharged, through the distillate cooler and the solenoid-operated dump valve, to the ship's service tanks (figs. 6–2B and 6–2C).

In some vertical-basket units, the discharge rate of the distillate pump is controlled automatically by a drain controller. The drain controller maintains a positive water level in the flash tank so that the pump will not become vapor-bound. Later models of vertical-basket units have been equipped with a recirculating line (figs. 6–2C) to the flash tank, instead of a drain controller. A throttle valve is included in the recirculating line. The recirculating line supplies relatively cold fresh water to the flash tank. The cooling water reduces the temperature of the distillate below the flash point; thus vapor lock within the distillate pump is prevented. The recirculating line also ensures, through control of the throttle valve, a positive suction head on the distillate pump.

Under normal operating conditions, the vertical-basket distilling unit produces distillate with less than 0.065 epm chloride (0.25 grains salt per gallon). If the unit is to produce relatively pure distillate, it is essential that salt water be prevented from entering the vapor and condensate systems. To prevent salt-water contamination of the ship's fresh-water supply, a salinity cell is provided

in each of the unit's fresh-water lines. If a salt-water leak should develop in the distillate circuit, the salinity indicator actuates the solenoid dump valve, which diverts the contaminated water to the bilge until the unit can be secured and the leakage stopped.

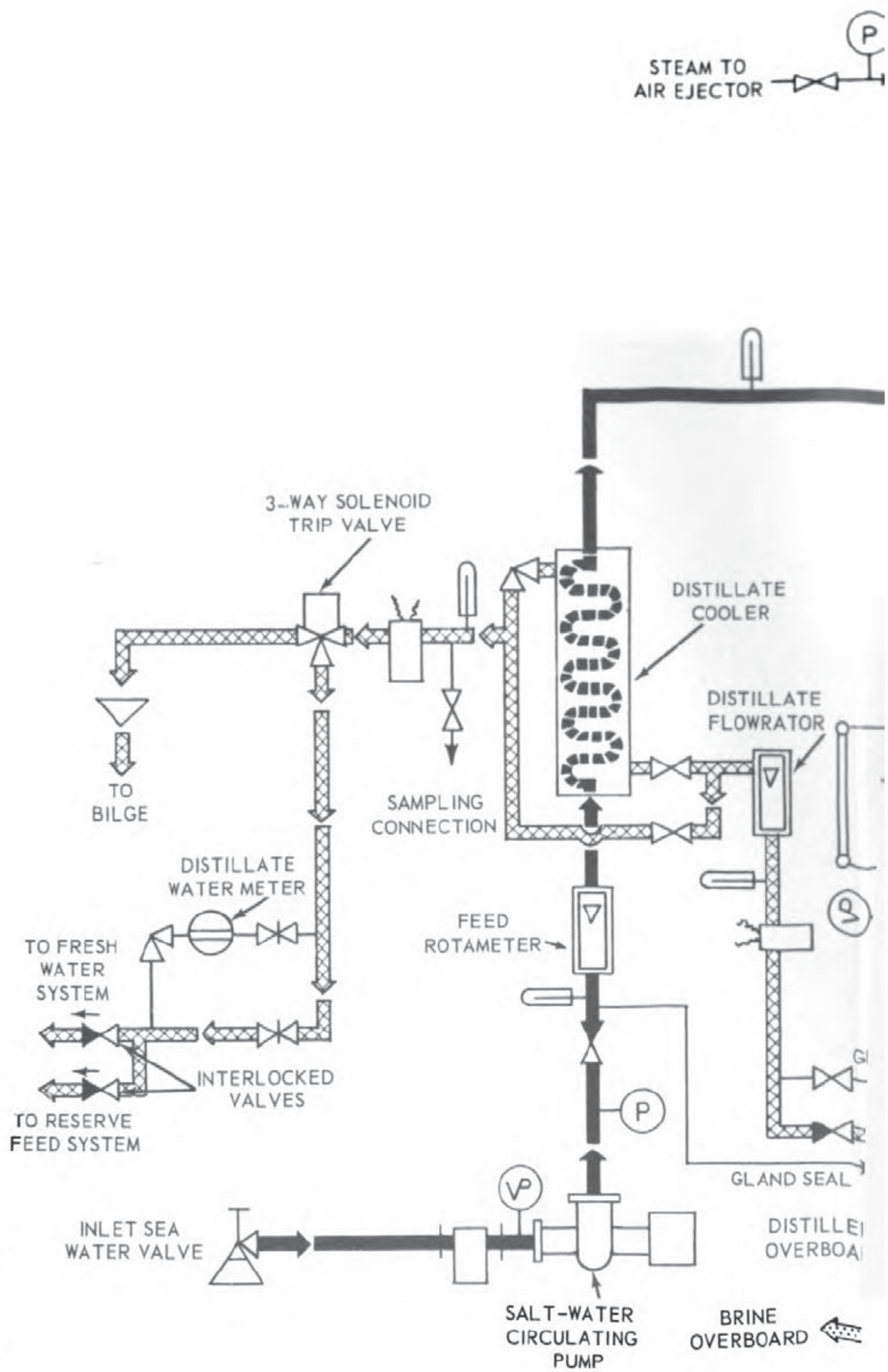
NONCONDENSABLE GASES.—Air and other noncondensable vapors in the distiller condenser are removed and vacuum is maintained throughout the evaporator units by an air ejector. The ejector is of the single-nozzle, single-stage, steam-jet type. (See *Machinist's Mate 3*, NavPers 10522.) The ejector is mounted on the side of the distiller condenser, and takes its suction from a specially baffled section within the distiller condenser. Vent lines and interconnecting vapor-piping connect components in which vacuum must be maintained. The degree of vacuum maintained is dependent upon the heat balances and ambient conditions.

The air ejector removes the air and other noncondensable vapors from the distiller condenser by utilizing the energy in the high-pressure steam. The gases entering the suction of the ejector are entrained by the steam jet from the nozzle and are carried through the diffuser, where the pressure is raised to that of the atmosphere. The ejector discharges into a surface after-condenser, where the steam is condensed and the noncondensable gases are vented to the atmosphere.

FLASH-TYPE DISTILLING UNITS

The first five-stage flash-type distilling unit (50,000 gallons per day) was tested late in 1955, and two-stage units with smaller capacity were being placed in service on DD–931 class destroyers early in 1956. The basic principle of operation of the relatively new flash-type distilling unit is described in *Machinist's Mate 3*, NavPers 10522. The Griscom-Russell two-stage flash-type distilling unit is described in this section.

In the Griscom-Russell unit, sea-water feed is heated



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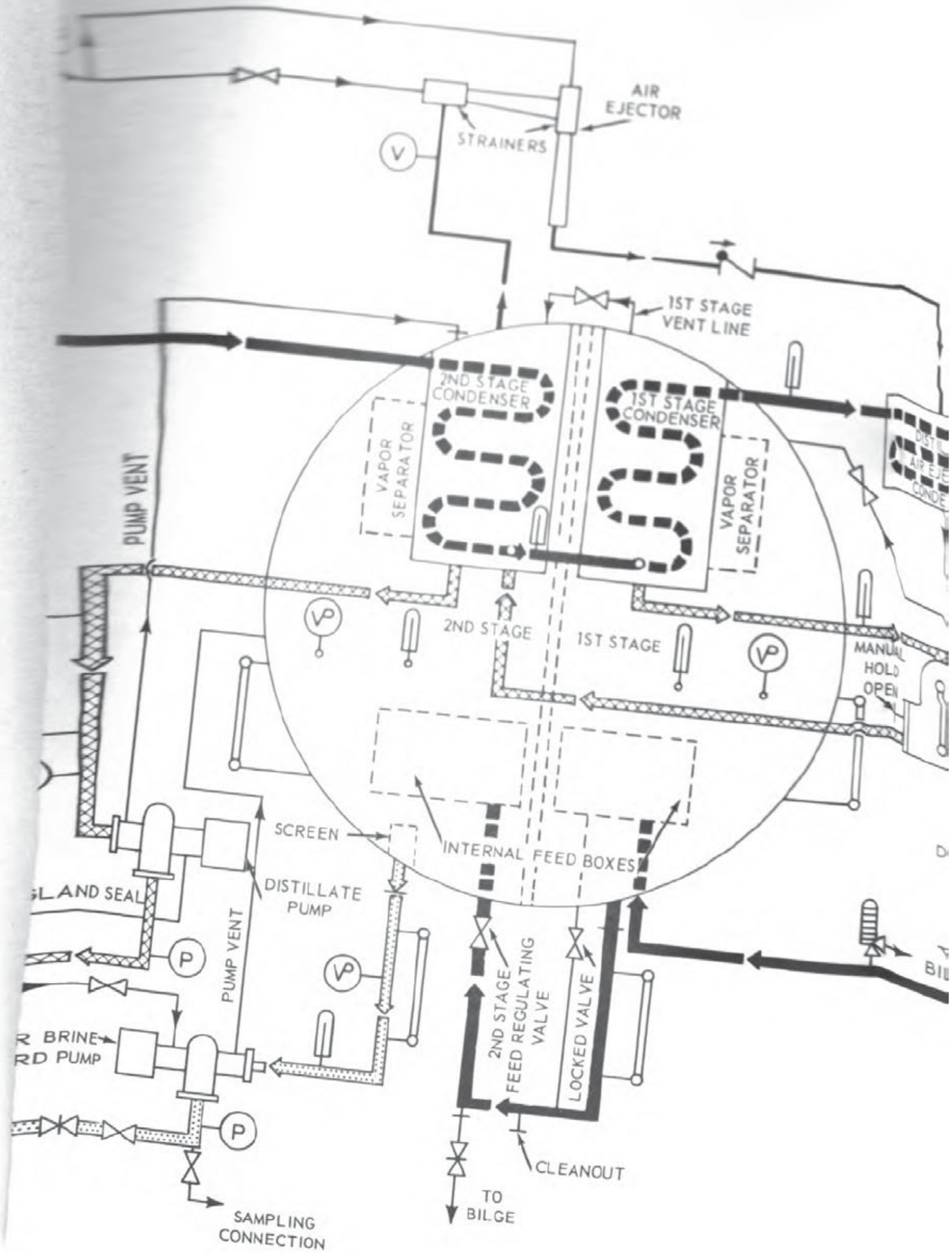
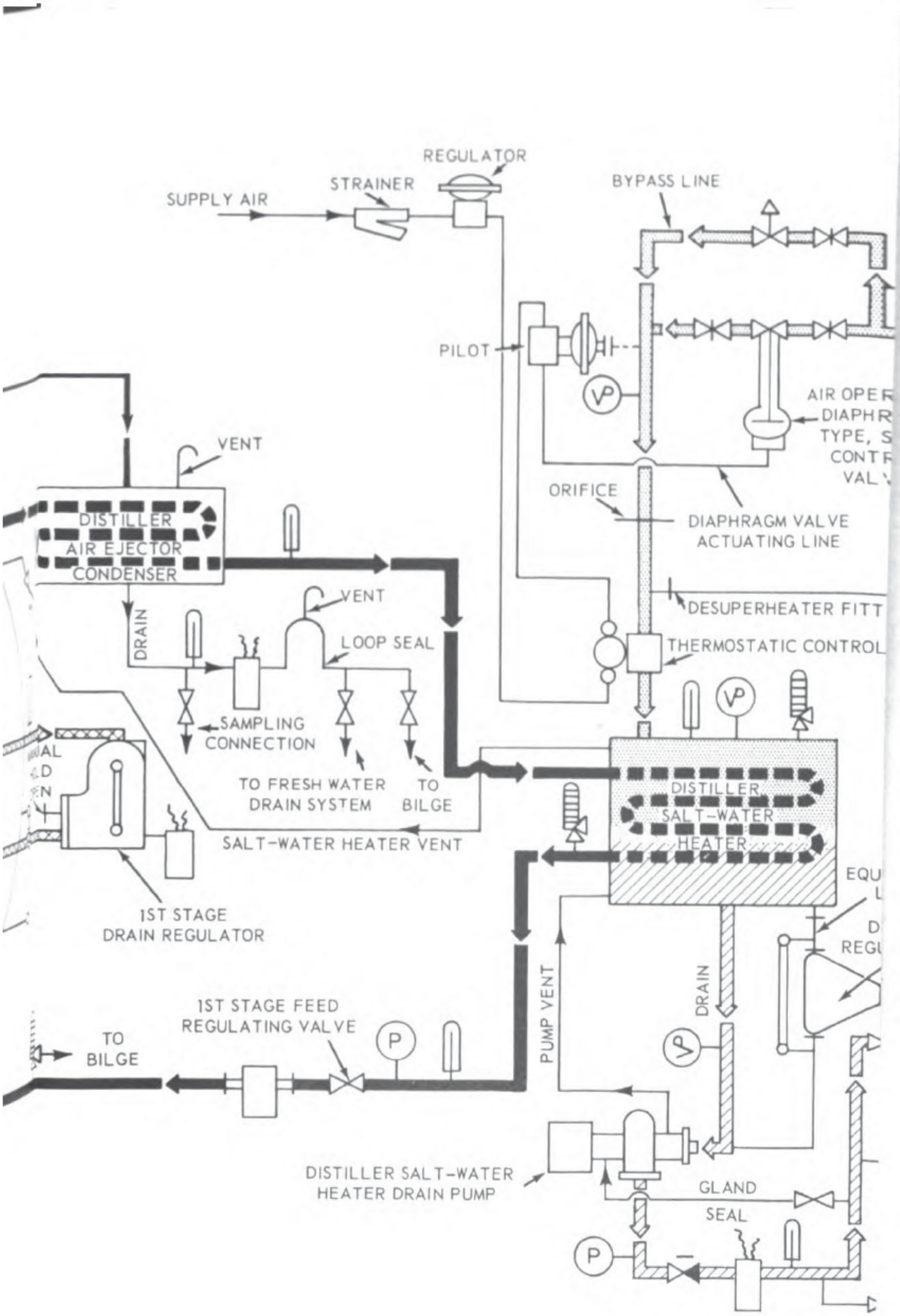


Figure 6-3.—Diagrammatic arrangement



...o-stage flash distilling unit (Griscom-Russell).

in a series of heat exchangers. The heated feed is discharged into the first of two vacuum chambers. When the hot feed is released within the chamber, a portion flashes or vaporizes because the pressure in the vacuum chamber is lower than the saturation pressure corresponding to the temperature of the hot feed. The vapor is condensed on the tubes of a distiller condenser by the salt-water feed flowing through these tubes.

The feed which does not vaporize in the first chamber is discharged into the second vacuum chamber, which is at a still lower pressure (higher vacuum) than the first chamber. The vapor formed and condensed in the second chamber mixes with that from the first vacuum chamber to form the distillate output of the unit. The rated capacity of the unit, for continuous operation, is 12,000 gpd when steam is supplied to the salt-water heater at 5 psig and the feed flow to the unit is 165 gpm at 85° F.

Components of a Two-Stage Flash Unit

The basic component of the Griscom-Russell unit is the distiller shell. The shell is divided to form the two stages (flash or vacuum chambers) of the unit. Most accessories for the unit are mounted directly on the shell. The piping system of the unit includes the essential pumps and strainers and an electrical salinity-indicator system. The relative location of these components and the flow circuits of the unit are shown in the diagrammatic arrangement of the unit, figure 6–3. Refer to that figure and trace the various circuits; become familiar with the relative location of the components as you study the following description of the distilling unit.

DISTILLER SHELL AND INTERNAL PARTS.—A horizontal cylinder, the distiller shell contains the two flash (vacuum) chambers; each flash chamber contains a feed-inlet box, a vapor separator, and a distilling condenser.

The first- and second-stage FLASH CHAMBERS are separated from each other by a hollow vertical wall through

the center of the distiller shell. In each chamber, the vapor separator and the distilling condenser are located at the top and the feed-inlet box is located at the bottom.

Access openings to each flash chamber are provided through the front of the distiller shell. Sight glasses are provided on the side of each flash chamber for observing the conditions within the flash chamber during operation. Gage glasses mounted on the access covers indicate the level of the water within each flash chamber. A screen is fitted over the suction connection to the brine-overboard pump to prevent foreign matter, which may enter the distiller shell, from passing into the brine pump.

Hot feed enters the distiller shell through the FEED-INLET BOXES. The construction of a feed-inlet box is illustrated in figure 6–4.

A series of orifice plates is bolted to the bottom of the box. A spreading plate is located directly above the orifices. An assembly of three plates with staggered

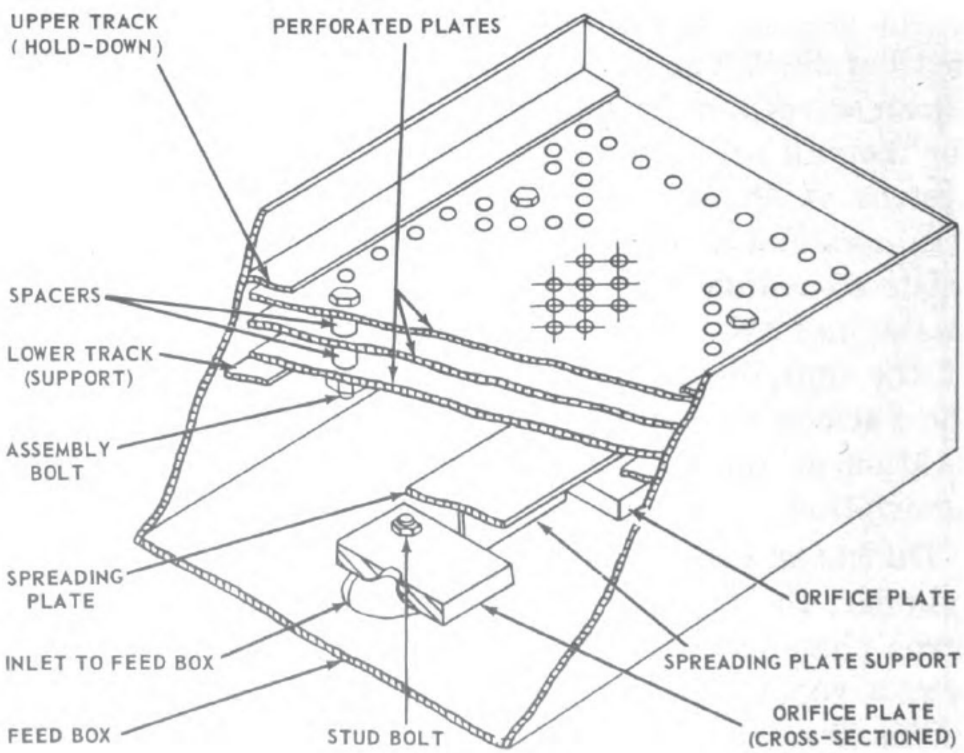


Figure 6–4.—Feed-inlet box.

perforations is held in place near the top of the box by two tracks which run along each side. The front of the feed-inlet box is removable; the assembly of perforated plates may be removed, through the access opening in the front of the distiller shell, to expose the individual orifice plates.

Vapor which flashes from the hot feed in the feed boxes flows to the VAPOR SEPARATORS. Each vapor separator is mounted in an opening in the plate which separates the distiller condenser from the flash chamber. A separator consists of several rows of vertical hooked vanes. These vanes are arranged to change the direction of flow of the vapor several times, and to trap and remove all entrained moisture.

The flash vapor from each stage is condensed on the shell side of the DISTILLER CONDENSER in each flash chamber. The salt-water feed flowing through the tubes of the condenser is heated as it absorbs the heat given off by the vapor as it condenses. The distillate collects in the bottom of the condenser.

The distiller condensers are of the straight-tube type; the tubes are roller-expanded into the tube sheets. A removable head at each end of the condenser provides access to the inside of the tubes. Each head is designed to direct the flow of the water through the tubes in eight passes. The heads are fitted with vents, drains, and pencil zincs. A plate welded to the shell provides support at the middle of the tube bundle. A diaphragm-type expansion joint between the rear shell head and the rear tube sheet allows for differential expansion of the tubes. Several baffles are arranged within the shell to direct the flow of the vapor through the shell from the warmest pass to the coolest pass. A separate baffle around the vent connection on each condenser forms an air cooling section; in this section the air and other noncondensable gases are forced to travel across a portion of the coolest pass of the condenser before they are released. This arrangement

reduces the volume of gas going to the air ejector and the vapor loss through the air ejector.

ACCESSORIES.—Most of the accessories for the Griscom-Russell two-stage unit are mounted directly on the distiller shell. These accessories include heat exchangers, drain regulators, flow indicators, an air ejector, a dump valve, and numerous thermometers, pressure gages, and fittings. Many of these accessories are similar in design to and operate on the same principles as comparable accessories used in connection with the submerged-tube distilling unit. (See *Machinist's Mate 3,* NavPers 10522.)

In addition to the distiller condensers, the distilling unit requires a salt-water heater, an air-ejector condenser, and a distillate cooler. These HEAT EXCHANGERS are of the same basic design; they differ principally in size, number of tubes, and the method by which the tubes are suspended.

The required level in the suction line between the salt-water heater and its drain pump is maintained by the SALT-WATER HEATER DRAIN REGULATOR. This regulator is of the ball-float external-valve type. The construction of the regulator is shown in figure 6–5.

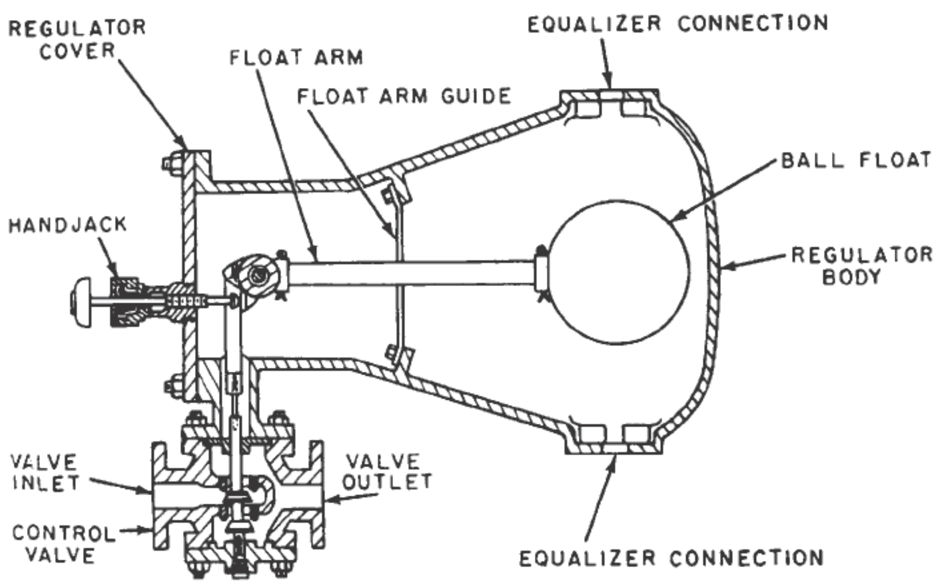


Figure 6–5.—Salt-water heater drain regulator (Griscom-Russell).

The body of the drain regulator is connected in parallel with the suction line to the salt-water heater drain pump. The regulator maintains a level in the suction line by throttling on the drain-pump discharge which passes through the external control valve on the drain regulator. A handjack on the regulator cover can be used to manually hold the valve open. A gage glass is provided on the regulator body to show the level being held in both the body and in the suction line to the salt-water heater drain pump.

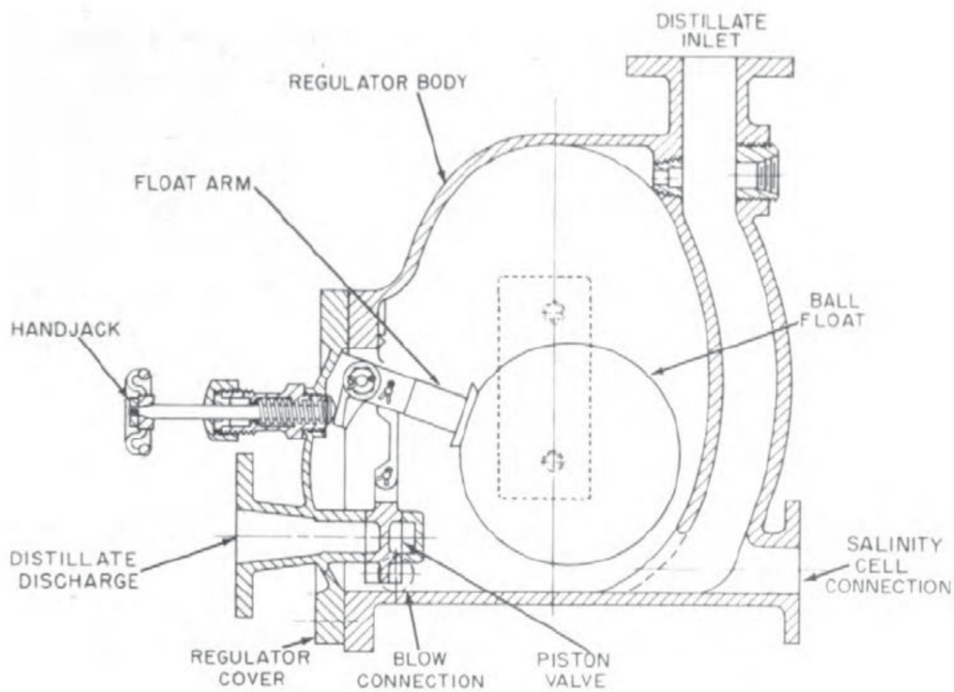


Figure 6–6.—First-stage distillate drain regulator.

The flow of distillate from the first-stage distiller condenser to the second-stage distiller condenser is controlled by the FIRST-STAGE DISTILLATE DRAIN REGULATOR. This regulator is of the ball-float internal-valve type. The construction of the regulator is shown in figure 6–6.

The distillate from the bottom of the first-stage distiller condenser enters the top of the drain regulator,

passes through the body, and is discharged through the piston-type valve into the bottom of the second-stage distiller condenser. A gage glass is provided on the regulator body to indicate the level within the body. A handjack on the regulator cover can be used to hold the valve open manually. The regulator is self-venting.

The salinity of the distillate at various points within the distillate circuit is indicated by an electrical SALINITY INDICATING SYSTEM. The system includes five cells. One cell is installed in each of the following locations: distillate outlet from the distillate cooler; distillate inlet to the distillate cooler; distillate drains from the first-stage distiller condenser; salt-water heater drain pump discharge; and air-ejector condenser drain line (fig. 6–3). An alarm sounds whenever the salinity at any cell exceeds 0.065 epm. All cells except the one in the distillate-cooler outlet register on the salinity indicating panel. The arrangement is such that when the salinity of the distillate exceeds 0.065 epm the cell in the outlet of the distillate cooler causes the solenoid of the THREE-WAY TRIP VALVE to be de-energized. This causes the valve to trip, and the contaminated distillate is discharged to the bilge. Once the valve has been tripped, the distillate will continue to flow to the bilge until the valve is reset manually.

The distilling unit is provided with VENTS at numerous points (see fig. 6–3). The salt-water heater shell is vented, through a line with a control valve, to the shell of the first-stage distiller condenser. The first-stage distiller condenser is vented, through a line with a control valve, to the second-stage condenser. The second-stage condenser is vented to the atmosphere through the air ejector and air-ejector condenser.

The salt-water heater drain pump is vented to the salt-water heater shell. The brine-overboard pump is vented to the second-stage flash chamber. The distillate pump is vented to the second-stage condenser.

All salt-water heads are vented to the atmosphere through individual vent cocks.

Circuits of a Two-stage Flash Unit

While flash units differ from submerged-tube units in design, the same types of circuits are found in both types of units. The circuits of the Griscom-Russell flash unit are described here under the headings of steam, feed, and vapor and distillate circuits, and the air-ejector systems.

STEAM CIRCUIT.—The heat required for the distillation process is provided by steam from the auxiliary exhaust main. The steam is supplied to the salt-water feed heater. (See fig. 6–3.)

The steam pressure is reduced from 15 pounds to 5 pounds by an air-operated diaphragm-type STEAM CONTROL VALVE. This valve is operated from a 20 psi air supply line, and maintains 5 pounds of steam pressure ahead of the ORIFICE in the steam line. After passing through the orifice, the steam is desuperheated by a DESUPERHEATER NOZZLE in the steam line. The steam then enters the shell of the SALT-WATER HEATER and condenses outside of the tubes. The condensate is removed from the heater by the SALT-WATER HEATER DRAIN PUMP and is discharged through a salinity cell and a DRAIN REGULATOR to the bilge, to the steam-drain collecting system, or to the ship's condensate system.

A THERMOSTAT is installed in the steam line down stream of the desuperheating nozzle. The thermostat protects the salt-water heater from overheating in the event that the desuperheater water supply should become inadequate for any reason. When the steam temperature rises above 400° F. the thermostat shuts off the air to the pilot control and bleeds off air which may be creating a pressure on the diaphragm of the control valve; this action causes the valve to close.

Desuperheating water may be furnished from the salt-water heater drain pump when the distilling unit is in operation; however, the water must be supplied from the ship's condensate system when the unit is being started.

FEED CIRCUIT.—The SALT-WATER CIRCULATING PUMP takes feed, through a strainer, from a sea chest. The sea-water feed is discharged through the FEED ROTAMETER and through the tubes of the DISTILLATE COOLER in a single pass. From the distillate cooler, the feed flows through the tubes of the SECOND-STAGE DISTILLER CONDENSER where the feed condenses the vapor released in the second stage. The feed then passes through the tubes of the FIRST-STAGE DISTILLER CONDENSER where it performs a similar function. (The salt-water feed is heated as it passes through the distiller condensers by absorbing the latent heat of condensation. This reduces the amount of heat to be absorbed in the salt-water heater.) From the first-stage distiller condenser, the feed flows through the distiller AIR-EJECTOR CONDENSER where a little more heat is absorbed; it then flows into the distiller SALT-WATER HEATER. The final heating of the feed is accomplished as the feed makes six passes through the tubes of the heater. The heated feed passes through the FIRST-STAGE FEED REGULATING VALVE and a Macomb-type strainer into the FIRST-STAGE FEED BOX.

Since the pressure in the first-stage flash chamber is lower than the saturation pressure corresponding to the temperature of the salt-water feed, the water will flash to the lower pressure and thus release vapor. Most of the flashing takes place as the water emerges from the orifices in the feed box. The flash vapor and feed are distributed across the feed box by the spreading plate and rise through the three perforated plates which further distribute the vapor across the entire box.

The feed which does not vaporize in the first stage flows out through an external loop-seal and into the SECOND-STAGE FEED BOX. (The pressure differential between the two stages causes the feed to flow through the loop seal.) Since the second stage is at a lower pressure (higher vacuum) than the first stage, an additional portion of the feed vaporizes in the second-stage flash chamber. The brine remaining in the second stage after

flashing occurs flows out of the distiller shell, through an internal protective screen, and is discharged overboard by the BRINE-OVERBOARD PUMP.

VAPOR AND DISTILLATE CIRCUITS.—The vapor flashed from the salt-water feed in the first-stage flash chamber rises and passes through the FIRST-STAGE VAPOR SEPARATOR into the FIRST-STAGE DISTILLATE CONDENSER. The vapor condenses on the outside of the tubes and transfers its latent heat to the incoming feed. The distillate flows through the external FIRST-STAGE DRAIN REGULATOR and into the bottom of the second-stage condenser where it flashes to the lower pressure in the second-stage condenser.

The vapor flashed from the feed in the second-stage feed box rises and passes through the SECOND-STAGE VAPOR SEPARATOR into the SECOND-STAGE CONDENSER. After condensing on the outside of the tubes, the distillate mixes with that from the first-stage condenser and is removed from the second-stage condenser shell by the DISTILLATE PUMP.

The discharge from the distillate pump passes through a salinity cell and the DISTILLATE FLOWRATOR into the distillate cooler where the distillate is cooled by the incoming salt-water feed. From the cooler, the distillate passes through the salinity cell which controls the THREE-WAY SOLENOID TRIP VALVE. Depending on the purity of the distillate as it passes through the last salinity cell, the three-way valve will direct the distillate to the bilge or to the ship's fresh water system or reserve feed system.

AIR-EJECTOR SYSTEM.—Air and other noncondensable vapor may enter the system dissolved in the feed water, and possibly by leakage at the various vacuum joints. These noncondensable gases are removed and the required vacuum is maintained at the second-stage distiller condenser by a TWO-STAGE AIR EJECTOR. The construction of the air ejector is shown in figure 6–7.

Steam for both stages of the ejector is applied from

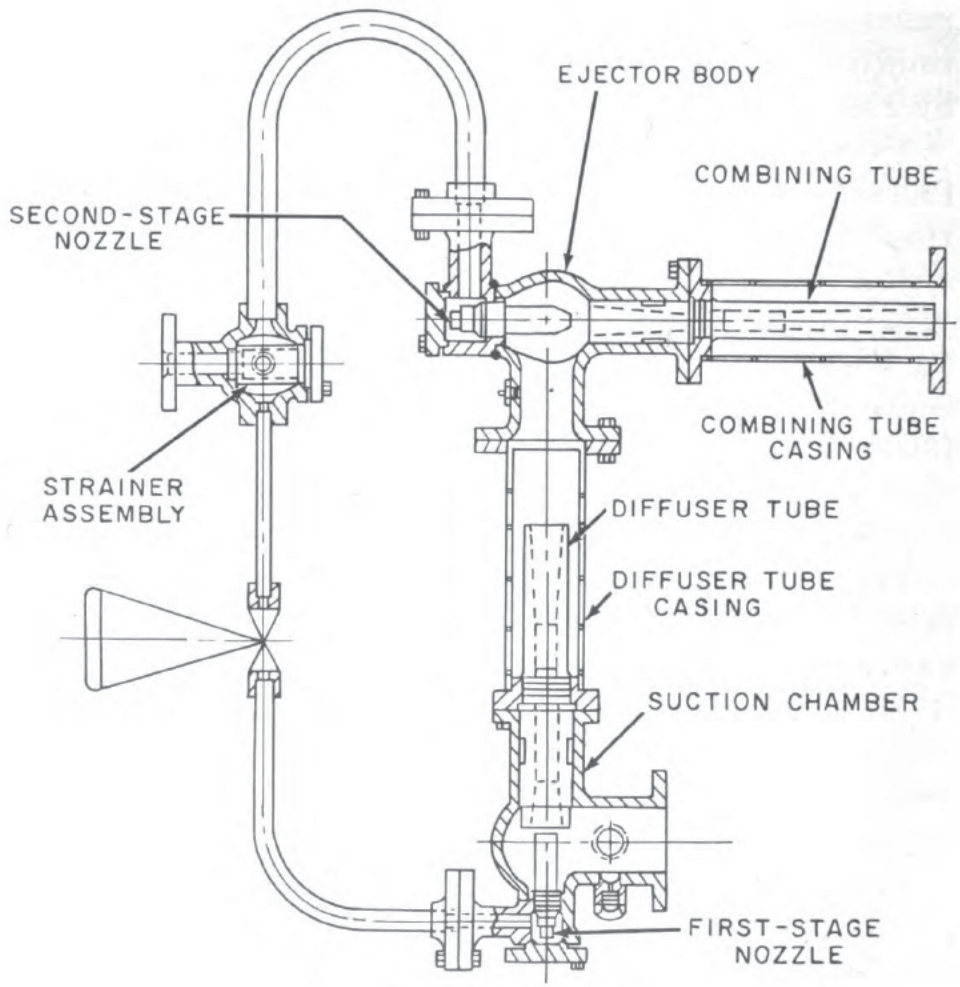


Figure 6–7.—Two-stage air ejector.

a 150 psig steam line. The first stage of the ejector takes its suction from the coolest portion of the second-stage distiller condenser. The gases enter the inlet of the first-stage nozzle at the mixing chamber and are entrained by the steam flowing from the nozzle. The gases are carried through the diffuser and are discharged into the mixing chamber of the second-stage nozzle. The gases are again entrained by the steam flowing from the second-stage nozzle and are carried through the second-stage diffuser. From the second-stage diffuser the gases and steam are discharged into the AIR-EJECTOR CONDENSER. The steam is condensed by the salt-water feed

which flows through the condenser tubes in three passes. The condensate is discharged from the condenser shell, through a salinity cell, to the drain collecting system or to the bilge. The noncondensable gases are discharged to the atmosphere through the vent in the top of the condenser shell.

MAINTENANCE OF LOW-PRESSURE DISTILLING UNITS

Some of the maintenance procedures for units of new design are, in many respects, basically the same as those for components of submerged-tube distilling units. General information on the care of strainers, cleaning air ejectors, scaling evaporator tubes, cleaning heat exchangers, and the care of zincs is given in *Machinist's Mate 3,* NavPers 10522. Additional information on the maintenance of the various types of distilling units is provided in this section. Detailed information on the procedures to be followed in maintaining any distilling unit must be obtained from the applicable manufacturer's technical manual or from approved instructions.

Chemical Cleaning of Distilling Units

An approved method of cleaning distilling units by circulating dilute acid through the unit is described in the pamphlet, *Chemical Cleaning of Low-Pressure Submerged-Tube Distilling Units,* NavShips 250–551–1. Acid cleaning of distilling units may be performed only when it is recommended by a naval shipyard or by a tender. This method of cleaning is authorized only for accomplishment by or under the direct supervision of personnel of a tender or of a shipyard, not by ship's force alone.

Acid cleaning permits cleaning a unit without dismantling it. Savings in time and in wear are considerably greater when acid cleaning is used than when manual cleaning is accomplished. However, when acid cleaning cannot be accomplished because of operational requirements or because of lack of availability, the unit must be cleaned mechanically.

Acid cleaning is supplementary to other types of distilling unit care. Neglect of feed treatment, cold shocking, or mechanical cleaning on the basis that the heavy coating of scale resulting from such neglect can be removed by acid cleaning at the next shipyard or tender availability is extremely undesirable.

Testing for Salt-Water Leaks in Submerged-Tube Distilling Units

The most practical method of checking the purity of distillate is by use of the electrical salinity-indicator system. Most indicating systems are equipped with audible and visual alarms, and with three-way solenoid dump valves for automatically directing the output to the bilge when the salinity exceeds the allowable limit.

Under normal operating conditions, the selector switch of the indicator system should be set to indicate the salinity of the combined output of all effects of the unit. The cell which indicates the salinity of the unit's output is located at the distillate cooler discharge. When high salinity of the unit's output is indicated, and the contaminated output has been directed to the bilge, the salinity of the product from each individual effect must be determined in order to locate the source and the cause of the contamination. On a three-effect submerged-tube unit, therefore, the selector switch must be turned successively to the distilling condenser drains, to the third-effect tube nest drains, and to the second-effect tube nest drains. The effect in which the contaminated vapor is being produced will be indicated by a high salinity reading on that effect. The contamination may be caused by leakage of salt-water into the distillate, or by priming.

Priming is usually caused by high or unsteady water levels, or by rapid changes in distilling unit vacuum. In most cases, fluctuations in vacuum are caused by faulty air-ejector operation. The primary causes of air-ejector trouble are low steam pressure, wet steam, an obstructed nozzle, or a clogged steam strainer. Faulty operation of

the distillate pump may also cause rapid changes in vacuum.

When high salt content of the distillate cannot be traced to the causes of priming, it is necessary to check the accuracy of the indicator. (See *Machinist's Mate 3*, NavPers 10522.) If the indicator is found to be accurate, the high reading may be a result of leakage of salt water into the distillate. However, a high reading may also be caused by foaming within the evaporator, as a result of a critical concentration of dissolved and suspended solids; or by carbon dioxide, ammonia, or other gas, given off from the feed water when it is heated, which is partially redissolved in the distillate and registers in terms of chloride content on the indicator. To determine whether or not the high reading is a result of salt water leakage, the following test may be made:

1. Check the salt content of the distillate by making a chemical salinity test.
2. Reduce the steam supply to the regulating valve until the output of the unit is greatly reduced.
3. When the unit has been stabilized at the reduced output, again check the salt content of the distillate. If the salinity remains the same as before, or if it is reduced, the trouble is due to an operating condition; if the salt content is higher at the lower output, a salt-water leak is indicated.

Leaks in the evaporator tube nests will not cause contamination of the tube nest drains when the distilling unit is in operation because the vacuum outside the tubes is higher than the vacuum within the tubes. Therefore, leaks in evaporator tubes must be detected when the distilling unit is being started or after it is secured. When a unit is being started, a high salt content in the first-effect tube nest drains may be caused by salt-water leakage from the shell into the tube nest. If the drains from an evaporator tube nest are regularly found to be contaminated after the unit has been secured, leakage in the tube nest is indicated.

Leakage in the tubes of heat exchangers and condensers may be detected by the proper manipulation of bypass valves, if provided; and by readings of appropriate salinity cells. If contamination disappears when a unit is bypassed, a leaky tube is indicated.

After the component in which the leak exists has been located, the component must be given a hydrostatic test before the leaking tube or joint can be located. When the leak is in a removable bundle (such as those found in vapor feed heaters within an evaporator shell, evaporator tube nests, and distilling condensers on Soloshell end-pull units), the bundle is withdrawn and a hydrostatic test at 50 psi pressure is applied on the tube side. When a leak occurs in a nonremovable bundle (such as those found in distillate coolers, air-ejector condensers, external vapor feed heaters), the tube-nest covers are removed and a test pressure of 50 psi is applied on the shell side of the unit. When a distiller condenser which is fitted with a diaphragm-tube expansion joint is being tested a test ring is required to replace the tube-nest cover.

A leaking tube may be repaired by plugging both ends of the tube with standard fiber or metallic plugs; or by plugging the ends with tapered hardwood plugs, in an emergency. However, too many plugged tubes will reduce the heating surface and, in some multipass heat exchanger units, they may cause excessive velocities within the unplugged tubes. Leaky tubes should be replaced when the plugging of tubes will cause an excessive reduction in heating surface. Replacement of tubes is usually accomplished by trained personnel of a tender or of a shipyard.

Care of Flash-type Units

The procedures for locating salt-water leaks within the components of a flash unit and for cleaning heat exchanger tubes in these units are basically the same as those applicable to units of the submerged-tube type.

Salt-water leaks in a flash unit are most likely to occur in the tubes of the first- or second-stage condensers or in the tubes of the distillate cooler. Scale does not form in the heat exchangers of a flash unit as rapidly as in those of submerged-tube units because of the lower operating temperatures in units of the flash type.

In flash units, the orifices of the feed boxes may become plugged or fouled and will require cleaning when symptoms of such trouble occur. Since the temperatures that exist in the feed boxes are well below the range in which salt-water scale forms, plugging or fouling at the orifices will most likely result from foreign matter which has been introduced into the unit.

If the distiller feed pump discharge pressure is normal, obstruction of the flash orifices in the first-stage feed box is evidenced by a reduced feed flow to the unit. Fouling of the orifices in the second-stage feed box is evidenced by water backing up into the first-stage shell. Water backing up into the first-stage shell may also be caused by insufficient pressure differences between the stages.

When the orifices in either feed box become obstructed, remove the access plate at the front of the distilling unit, remove the perforated plates from the feed box, and remove the obstructing material from the orifices. The feed boxes are so constructed that the front can be readily removed for access to the orifices.

Care of Vertical-basket Units

The principal advantage of the vertical-basket unit over the submerged-tube unit is that scale in it can be effectively removed by cold shocking. (See *Machinist's Mate 3,* NavPers 10522.) Vertical-basket units may be descaled by the acid-cleaning method when the process is recommended by a tender or by a shipyard. Acid cleaning should be accomplished after approximately 2,000 hours of operation, and at least every 6 months. If acid cleaning is not possible, the evaporators should be de-

scaled by hand. The basket heating sections can be lowered from their normal positions. The heating surfaces, the inside of the shells, and the equalizers should all be cleaned.

As in other types of distilling units, salt-water leakage in the heat exchangers of a vertical-basket unit may be detected by the use of the salinity-indicating system. When the source of leakage has been found, the leaking component is removed and tested hydrostatically. Defective tubes should be rerolled or replaced.

QUIZ

1. Heat for the distillation process in a vertical-basket distilling unit is supplied by
   (a) electric elements in the corrugations of the heating section
   (b) vapor from auxiliary compressors
   (c) heaters in the evaporator shell
   (d) steam from the ship's auxiliary-exhaust main

2. Condensate which forms in the first effect of a vertical-basket distilling unit may be discharged to the
   (a) heating section of the second effect
   (b) ship's reserve feed tanks
   (c) flash tank
   (d) distillate cooler

3. Trace the flow of feed from the circulating pump to the first effect of a vertical-basket distilling unit by listing in proper sequence, the principal components through which the feed passes.

4. How are liquid particles removed from the first-effect vapor in a vertical-basket distilling unit?

5. What are the functions of the first-effect vapor in a vertical-basket distilling unit?

6. What happens to the liquid particles which are separated from the vapor in both effects of a vertical-basket distilling unit?
   (a) They are discharged overboard
   (b) They are returned to the ship's condensate system
   (c) They flow to the flash tank
   (d) They flow to the first-effect heating section

7. In a vertical-basket distilling unit, what causes the condensate to flow from the second-effect steam chest to the flash tank?

8. The distillate produced by a vertical-basket distilling unit is the combined drains from the
   (a) first- and second-effect steam chests
   (b) distiller condenser and second-effect steam chest
   (c) separators, second-effect steam chest, and flash tank
   (d) first-effect steam chest and distiller condenser
9. What device is provided on a vertical-basket distilling unit to prevent the distillate pump from becoming vapor-bound?
10. How is contamination of the ship's fresh-water supply prevented when the salinity of the output of a vertical-basket distilling unit exceeds 0.065 epm?
11. What is the function of the air ejector on a vertical-basket distilling unit?
12. From what component of a vertical-basket distilling unit does the air ejector take suction?
13. What causes the hot feed which enters the flash chambers of a flash-type distilling unit to vaporize?
14. What are the principal components contained in each flash chamber of a flash-type distilling unit?
15. Are the perforated-plate assemblies in the feed-inlet boxes of a flash-type unit removable or nonremovable?
16. The moisture which is carried over with the vapor in a flash-type distiller is removed by
   (a) an impeller
   (b) a stack of disks
   (c) several rows of hooked vanes
   (d) an arrangement of horizontal baffles
17. Does the flash vapor in each stage of a flash-type distilling unit condense on the shell side or within the tubes of the distiller condenser?
18. What is the function of the salt-water heater drain regulator in a flash-type distilling unit?
19. What device controls the flow of distillate between the distiller condensers of a flash-type distilling unit?
20. List the locations of the salinity cells in a flash-type distilling unit.
21. In addition to determining the salinity of the output of a flash-type unit, what function is performed by the salinity cell in the distillate outlet of the distillate cooler?

22. After the three-way solenoid trip valve of a flash-type distilling unit has been tripped, will the valve automatically discharge the distillate back to the ship's service tanks when the salinity of the distillate returns to normal?

23. In a flash-type distilling unit, which of the following components is vented to the second-stage flash chamber?
    (a) Brine-overboard pump
    (b) First-stage distillate condenser
    (c) Salt-water heater shell
    (d) Air-ejector condenser

24. What is used to operate the steam-control valve of a flash-type distilling unit?

25. What is the source of desuperheating water when a flash-type distilling unit is being started?

26. Does feed for a flash-type distilling unit first flow through the salt-water heater or the distillate cooler?

27. In a flash-type distilling unit, what causes feed to flow from the first-stage feed box to the second-stage feed box?

28. From what component of the unit does the air ejector of a flash-type unit take suction?

29. When a submerged-tube distilling unit is being started, what is indicated by high salinity of the drains from the first-effect tube nest?

30. How is a leak within a component of a distilling unit located?

31. If the discharge pressure of the feed pump for a flash-type unit is normal, what is indicated by a reduced feed flow to the unit?

CHAPTER 7

HYDRAULIC AND PNEUMATIC EQUIPMENT

As an MM3, you learned that there are a number of auxiliary units outside the regular engineering spaces, and you became familiar with the operation of the auxiliary machinery. (As you know, most of the auxiliary units, including steering gear, anchor windlasses, deck winches, capstans, cranes, elevators, and pumps are operated hydraulically.) As an MM2, however, you will be required to know how to renew ram packing on hydraulic steering gears and elevators, and how to change seals and gaskets on hydraulic equipment. In addition, you will probably test, as well as maintain, other auxiliary equipment such as air compressors.

Detailed information concerning the operation of the various types of steering gear, and auxiliary machinery can be obtained from *Machinist's Mate 3,* NavPers 10522. Therefore, it may be advisable for you at this point to review the individual chapters dealing with pumps, auxiliary machinery, and compressors in the Navy training course *Machinist's Mate 3,* NavPers 10522.

Since the Navy is using more aircraft carriers than ever before, and you are required to know how to renew ram packing on elevators, you should become familiar with the individual components and systems installed on aircraft carrier elevators. Therefore, this chapter deals primarily with the operation and maintenance of elevators.

DESCRIPTION OF ELEVATORS

Carriers are provided with two or more inboard elevators, capable of handling airplanes between the flight deck and the hangar deck at relatively high speed. Shipboard elevators may be divided into two major classes: ELECTROMECHANICAL and ELECTROHYDRAULIC ELEVATORS.

Electromechanical Elevators

The platform of electromechanical elevators is raised and lowered by two groups of cables which pass over sheaves to the hoisting machinery. Two hoisting drums, coupled together, are driven through a reducing gear unit by an electric motor. The motor is of the two-speed type (full speed and one-quarter speed). Control arrangements are such that the elevator starts and runs on the motor high-speed connection, the low speed being used for deceleration as the elevator approaches the upper or lower limit of travel. The platform travels on two athwartship guides. Manually operated locks, equipped with electrical interlocks, are provided for holding the platform in the raised position.

Freight, bomb, mine, and torpedo elevators are similar in design features to the electromechanical airplane elevator.

Electrohydraulic Elevators

Aircraft carriers are provided with electrohydraulic elevators capable of handling planes between the flight and hangar decks at relatively high velocity. This class of elevators may be divided into two general types: the DIRECT-PLUNGER LIFT and the PLUNGER-ACTUATED CABLE LIFT.

DIRECT-PLUNGER LIFT ELEVATORS.—The platform of the direct-plunger lift elevator is raised and lowered by direct connection, under the platform, with two vertical hydraulic rams. During the hoisting operation, oil from a high-pressure tank, at a pressure of approximately 900 psi, is forced into the rams. Lowering is accomplished by

discharging the oil from the rams into an exhaust tank, which is under a pressure of approximately 230 psi. Pressure in the pressure tank (approximately 900 psi) is maintained by means of electrically driven variable-stroke pumps, which take suction from the exhaust tank. One of the pumps is capable of maintaining operation of the elevator at reduced speed.

The direct-plunger lift elevators may be considered as pneumatic-hydraulically actuated. On top of the confined hydraulic fluid in the high-pressure tank there must always be air under high pressure.

Special control valves (operated either by pilot valves or by an electric motor) in the pressure and exhaust lines regulate elevator speeds by varying the amount of oil admitted to, or discharged from, the rams. Positive stops and mechanical locks, interlocked with the elevator control circuit, enable the platform to be stopped, locked, and held in position at the flight deck level. An equalizer system maintains the platform at uniform level under conditions of unequal loading. Automatic quick-closing valves in the hydraulic fluid line prevent the sudden dropping of the platform in case of damage to the piping. In case of damage to the main pumps, the sump pumps will generally provide sufficient power for one upward run; otherwise the emergency run is made with the reserve capacity of the pressure tank. A hand-control system is provided for use when electric controls are damaged.

To provide adequate working space on the hangar deck while the after elevator platform is at the flight deck level, a small auxiliary pit elevator is often provided. This elevator is raised and lowered simultaneously with the main elevator. The operating pistons receive power from the same pressure tank and discharge into the exhaust tank as used by the main elevator.

PLUNGER-ACTUATED CABLE LIFT ELEVATORS.—The platform of the plunger-actuated cable lift elevator is raised by wire-rope cables fastened to the platform at two or

four symmetrically placed points. These cables, through a series of sheaves, are actuated by a horizontal ram located beneath the hangar deck. In case one group of cables should fail, instantaneously acting safety devices engage the guide rails of the elevator in order to stop and hold the platform.

One type of plunger-actuated cable lift elevator is the deck edge elevator. This type elevator is cantilever supported over the side of the ship and may be equipped with a hinge arrangement for stowage in a vertical position. The outboard section of the platform is tilted to its stowed position by a special rigging arrangement. Vertical movement is imparted to the platform by two sets of cables attached to the inboard corners. These cables are actuated in a manner similar to that employed by the inboard, or centerline, elevators described previously.

Figure 7–1 illustrates a cable lift type, inboard aircraft elevator used aboard the CVE–105 class aircraft carrier. There are two aircraft elevators aboard CVE–105 class carriers; one is located forward and the other is located aft. (Figure 7–1 illustrates the location, as well as the components, of the forward aircraft elevator.) Each elevator functions independently of the other. However, with respect to operation, duty, and cycle, both have the same characteristics and are constructed similarly. These elevators differ primarily in the position of their hydraulic engine and auxiliary equipment.

The remainder of this section deals with the major components of elevators. Detailed information concerning a specific type of elevator can be obtained from the manufacturer's technical manual for the particular type of installation.

Platforms

The elevator platform is used primarily to move aircraft between the hangar deck and the flight deck. The elevator platform forms a part of the runway of the

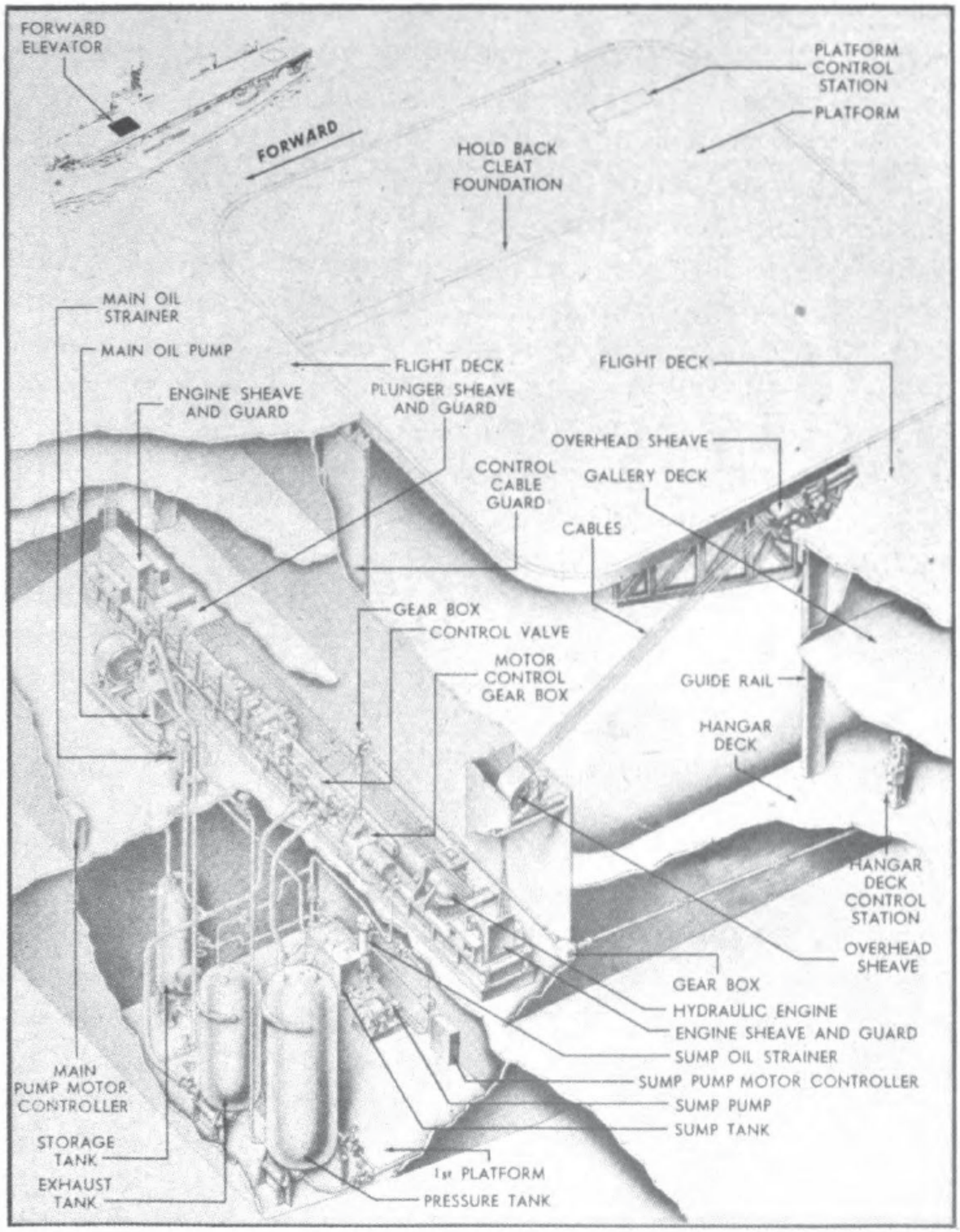


Figure 7–1.—Components of an aircraft elevator (CVE–105 class carrier).

flight deck and, when not in use, must be locked in place at the flight deck level.

A typical elevator platform is shown in figure 7–2 (CVE–105 class). The platform consists of three structural sections of angle steel, steel tubing, and plate, welded into one complete unit. The flooring, constructed

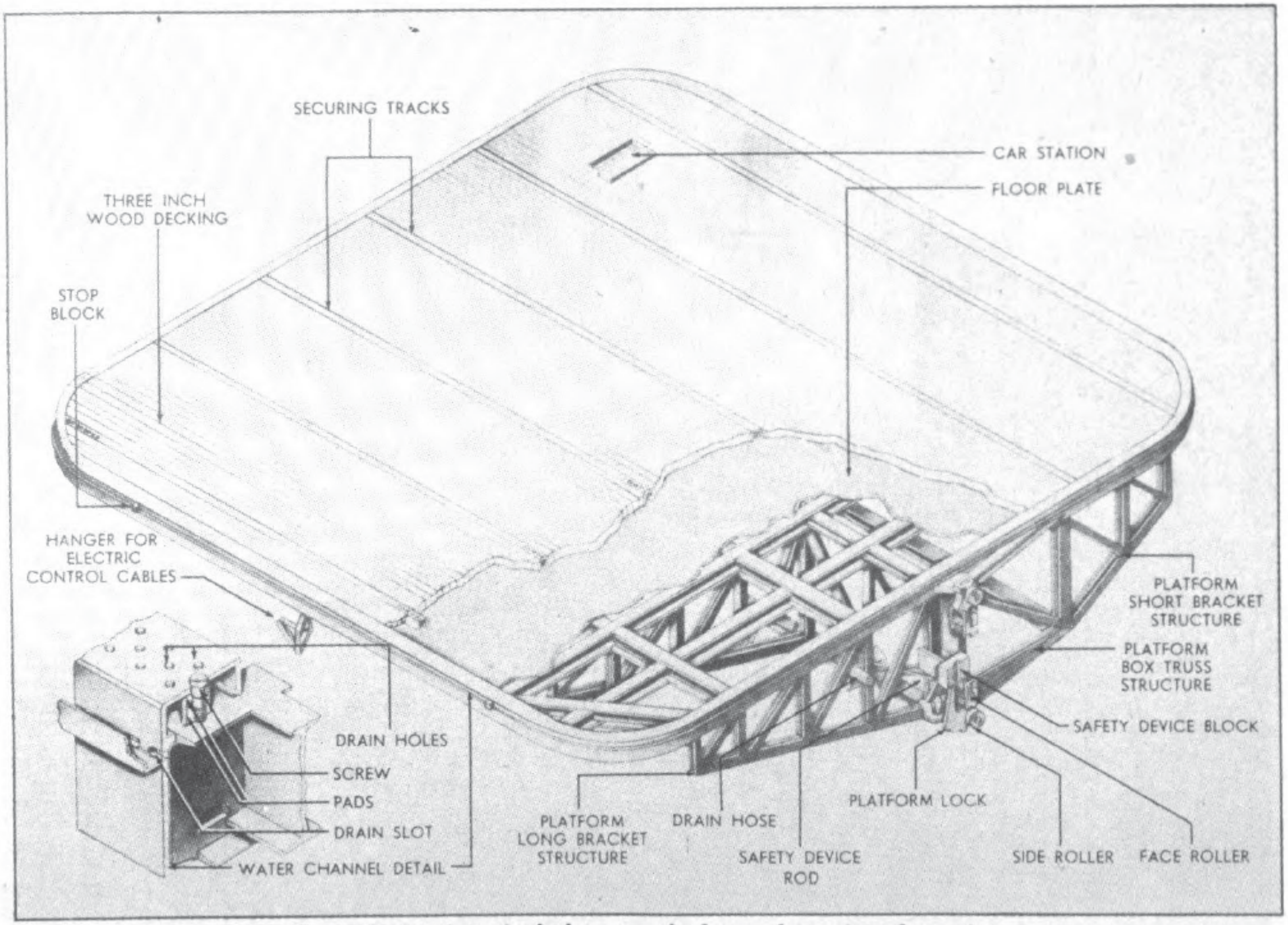


Figure 7-2.—A typical elevator platform of an aircraft carrier.

of three-inch wood (fig. 7–2), is securely anchored to the structure. Four roller type guide shoes, attached to the ends of the platform structure, run in steel channel rails which are secured to the ship structure.

There are two safety assemblies, one at each side of the platform. If a cable on either side fails, the safety device immediately engages the guide rail and prevents the platform from falling. When the platform is not in use, manually operated locks hold it in place, at the flight deck.

When the platform is locked at the flight deck, the securing tracks (fig. 7–2) permit a maximum of four planes to be lashed and stowed on the platform.

A waterway, built around the edge of the platform, prevents water from flowing through the hatchway to the hangar deck. Drains remove the water from the waterway.

Each elevator is supplied with two 7-conductor No. 16 gage wire traveling cables conforming to Navy Specification 15C1 Type MCOP–7. The cables connect the platform-control station with the motor controller. (The elevator platform-control station is located on the platform deck in a steel box built flush with the decking.) The cables are placed inside of the cable guard, or a sheet enclosure, so that they don't swing in the hatchway.

The car end of the traveling control cables is carried by the car cable hangar, a structural steel bracket welded to the platform. The outer end of the bracket is so shaped that the cables are in the cable guard at all times. The hatch cable hangar, a pipe type support, is an integral part of the traveling guard.

The stop block (fig. 7–2), mounted on the side of the elevator platform, is a rectangular cast steel block with a lip (at the top of the block) welded to the steel framework, at the sides of the platform structure. When the elevator platform reaches the flight deck, the lip engages a stop block on the edge of the flight deck, and stops the platform flush with the flight deck.

Guide-Shoe Rollers

On the CVE–105 class aircraft carrier, as well as other installations, four guide-shoe rollers guide the elevator platform in its travel between the hangar deck and the flight deck. A guide-shoe roller is illustrated in figure 7–3. The rollers, attached to the ends of the main box

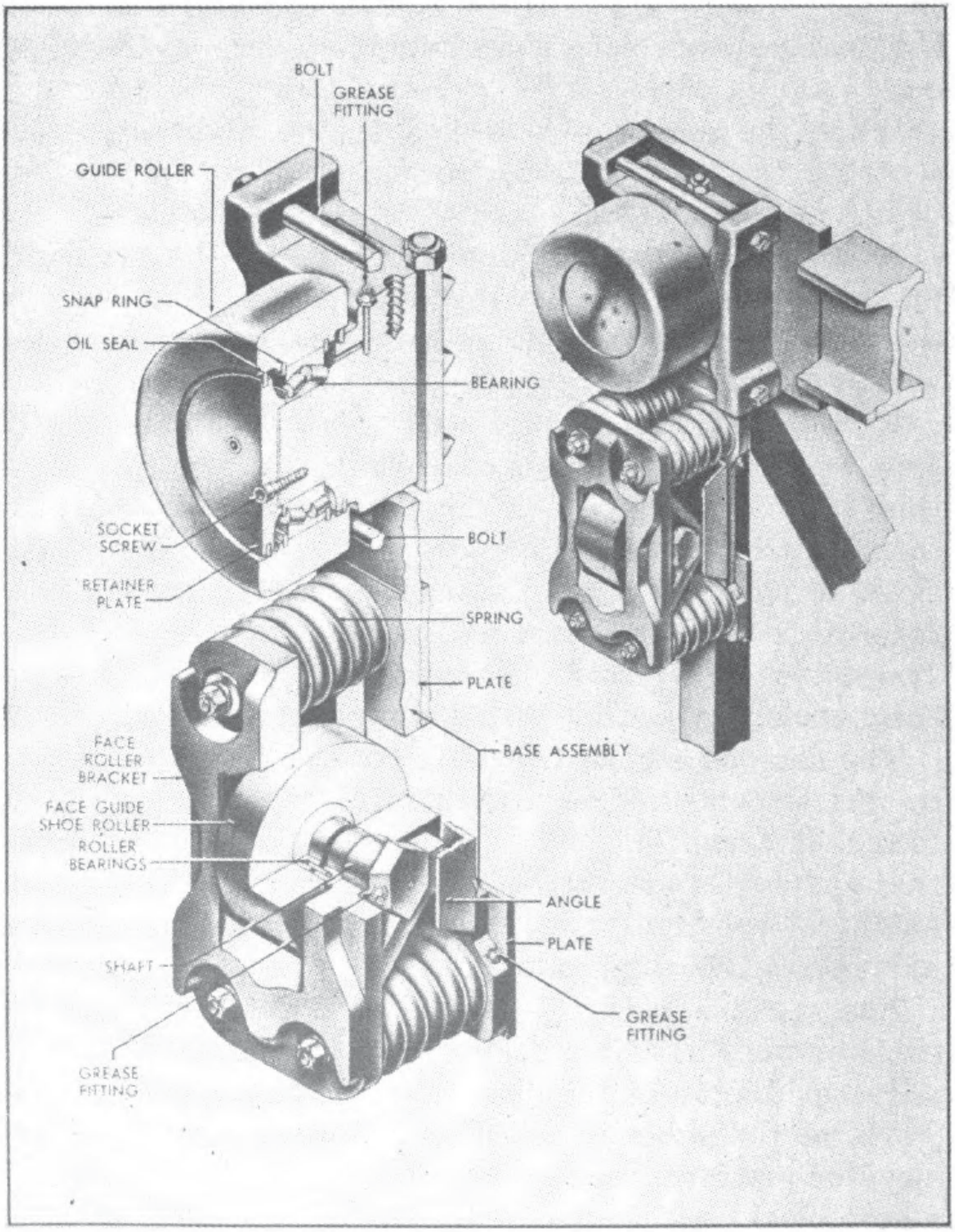


Figure 7–3.—Guide-shoe roller.

structure of the platform, ride in two steel channel-shaped guide rails which are secured to the ship's main structure. Two guide-shoe rollers are mounted on each side of the box structure of the elevator platform; one near the top and another near the bottom.

Each guide-shoe roller consists of two rollers. The side roller which is rigidly fixed, bears against the sides of the guide rail and takes the fore and aft load. This roller, constructed of steel, is provided with roller bearings. The outer race of the bearing is pressed into the roller, and held in place by means of snap rings (fig. 7–3). The inner race of the bearing has a slide fit on the roller bracket, and is held in position by the retainer plate.

The face roller (fig. 7–3) rides on the back surface rail and takes the load resulting from the roll of the ship. It has a steel roller face, and is provided with a roller bearing having four springs which act as shock absorbers, taking up the weight of the platform as the ship rolls. This spring action is limited by the shoulder on the roller bracket.

Locking Device

As mentioned previously, when the elevator is not in use, the platform locks (fig. 7–4) hold the platform at the flight deck level. The locking device consists of two locking latches (one on the port side and one on the starboard side of the platform), attached to the ship's main structure under the flight deck.

The locks are operated by swinging the hand-operating lever to the "ON" position, where it is automatically latched in place. The turning motion is transferred, through the tubular shafting, rods and links, to the latch-lever assembly which sets the latch lever under the platform-lock stop block. A cam, on the latch-lever assembly, operates a limit switch whose contact opens the safety interlock circuit.

The safety cam prevents the lock from being extended before the platform is up to the flight deck. As the plat-

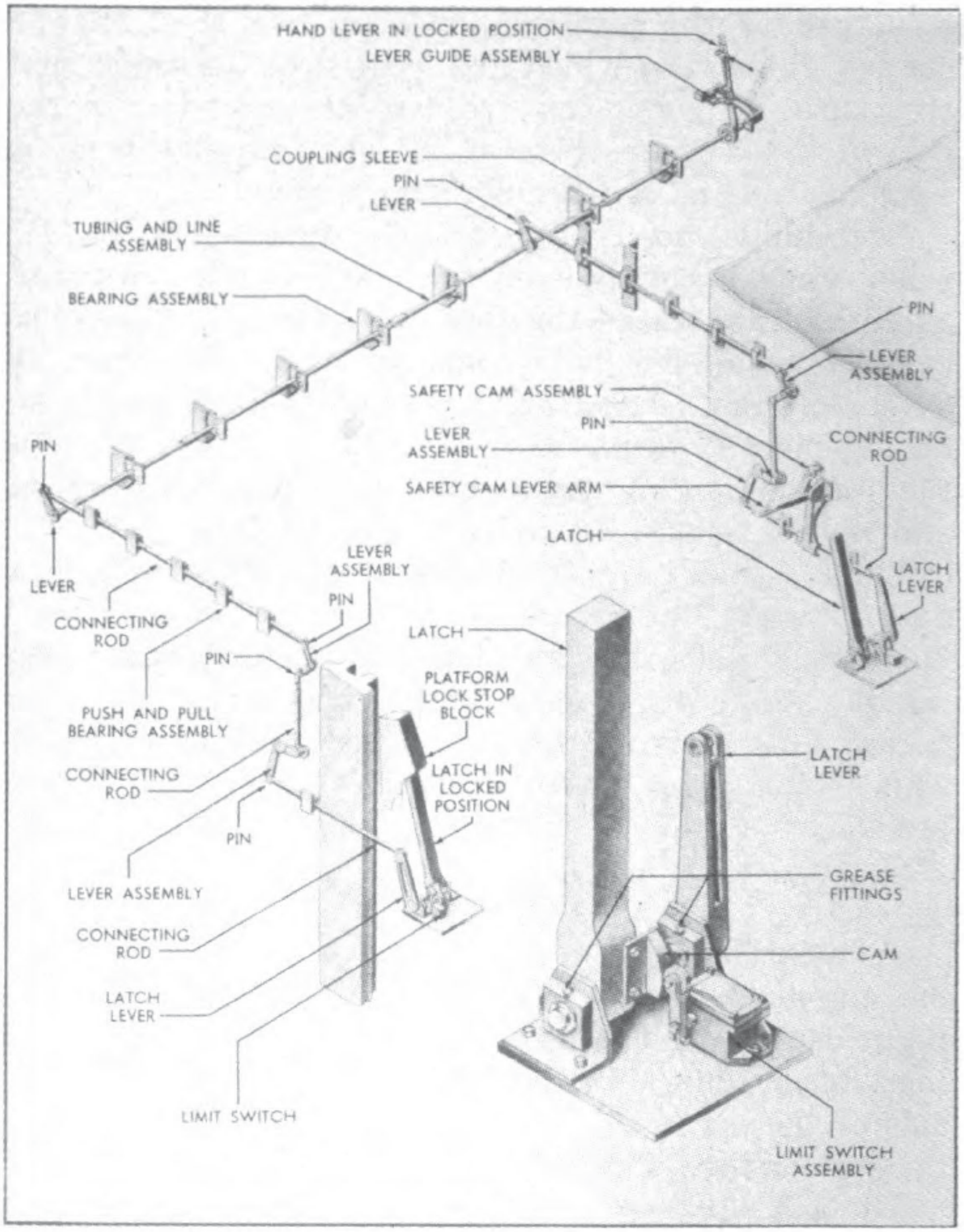


Figure 7–4.—Platform locks.

form approaches the flight deck, it engages a safety-cam assembly, withdrawing the cam from the front of the stop, clamped to the operating rod of the lock. The cam should not clear the stop collar until the platform is within 3½ inches of the flight deck level.

Figure 7–5 illustrates the safety-cam and hand-oper-

ating assemblies of an elevator platform lock, aboard the CVE–105 class aircraft carrier. Notice that the safety-cam assembly is a spring and lever arrangement, generally attached to one side of the elevator hatchway. (This assembly prevents the locking gear from being

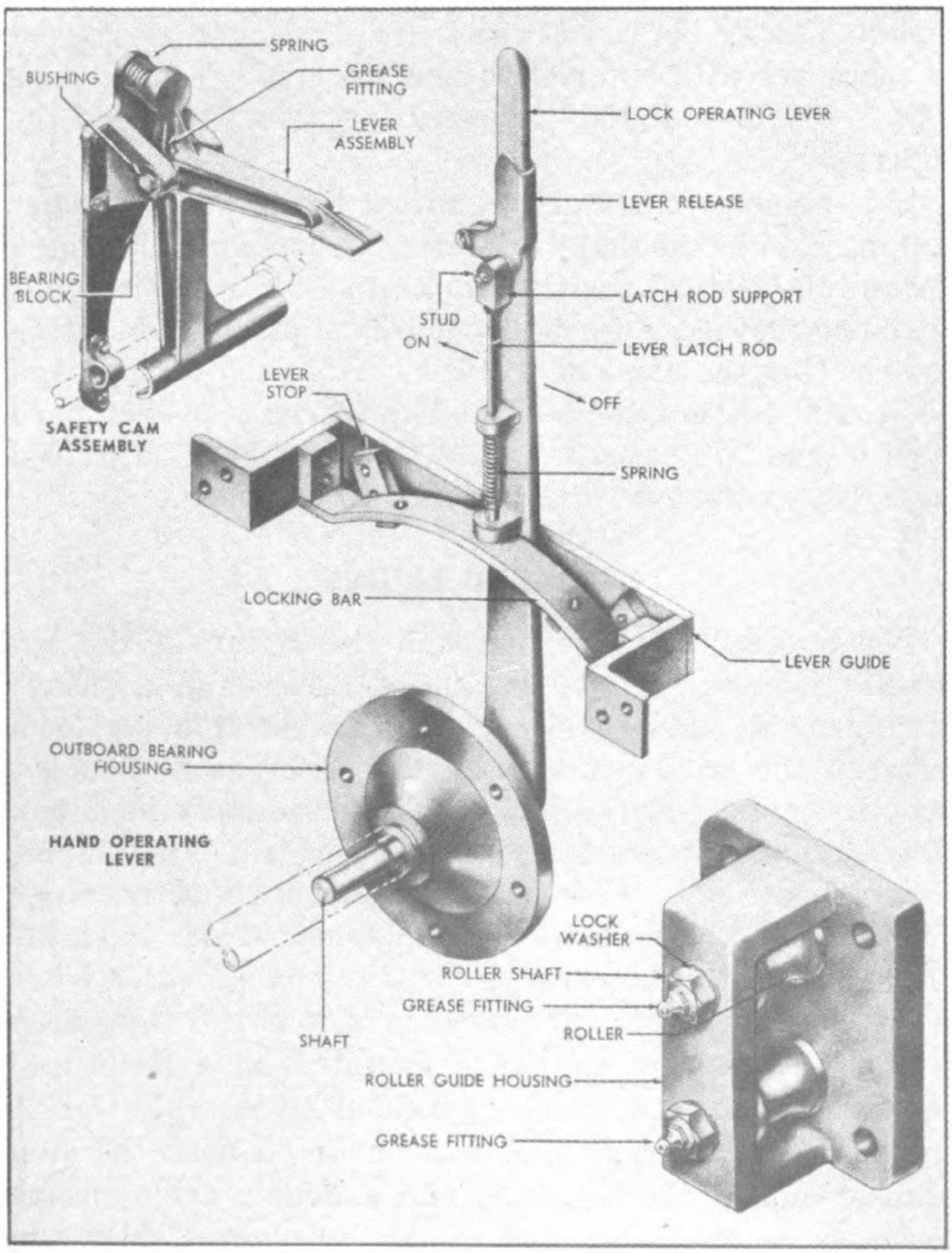


Figure 7–5.—Safety and hand-operating assemblies of a platform lock.

operated until the rising platform trips the lever. The safety assembly does not allow the locks to be released until the platform is within 3½ inches of the flight deck level, and in position for locking.)

The hand-operating assembly of the platform lock consists of a lever and latch located at the gallery walkway, opposite the hatchway. The lock guide rollers, mounted along the run of the lock operating gear, consist of a bracket with two rollers and pressure grease fittings (fig. 7–5). The tubular lock shafting moves between the rollers.

If it becomes necessary to adjust the locks for proper action, clamp the hand-operating lever and the latch levers in a vertical position, and remove the bearing pins at the link levers. Adjust the lengths of all the connecting rods so that the arms of the links are in the vertical and horizontal positions. When the hand lever is pushed hard over to the "ON" position, and the hand-lever latch rod engaged, see that both latches are fully locked.

HYDRAULIC ENGINE

The hydraulic engine, through the action of the hydraulic plunger, and by means of cables and a sheave arrangement, raises and lowers the elevator platform between the hangar deck and the flight deck. The hydraulic engine (fig. 7–6) is of the horizontally mounted, single-cylinder plunger type, with a traveling double sheave attached to the head of the plunger. Positive stops are provided at both ends of the plunger stroke. With the plunger in, the platform is down at the hangar-deck level. With the plunger out, the platform is up at the flight-deck level. The complete engine is mounted on a horizontal bedplate foundation, made of welded structural steel. A single 90° wrap cable sheave is mounted near the stop bracket end of the bedplate, and a double cable sheave assembly on the other end of the bedplate. Cables run from each end of the platform around the deflection

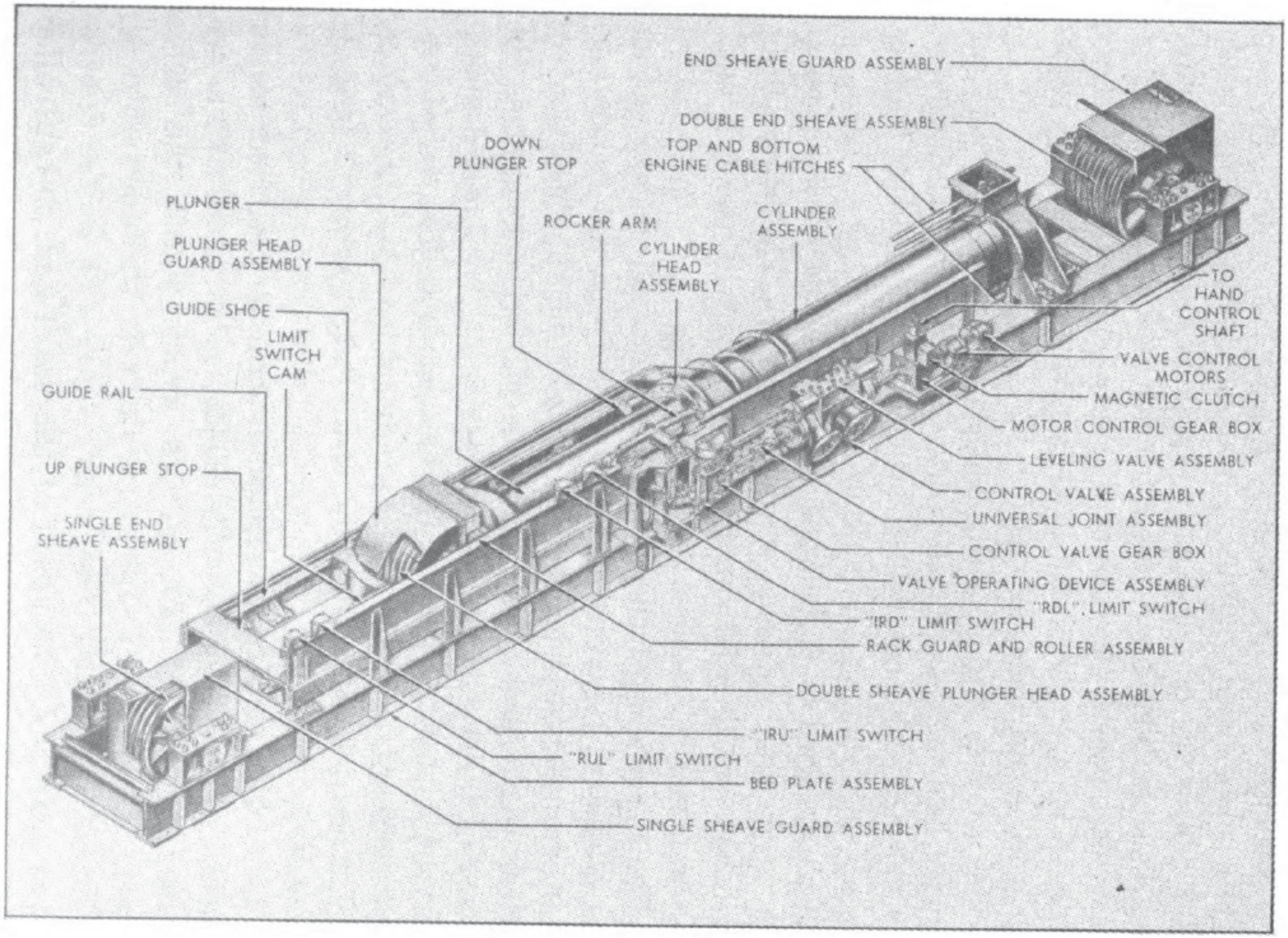


Figure 7–6.—Hydraulic engine.

sheaves, and around the double sheave on the head of the plunger, to the dead-end hitches on the cylinder. This cabling gives the platform a travel ratio of two-to-one over the plunger.

The closed-end cylinder casting provides the cable hitches and the mounting for the slack-cable safety device and switch. The open-end cylinder head casting is generally fitted with the bronze bushing in which the plunger slides. The cylinder head also is provided with the packing and gland assembly.

The control and leveling valves, the cam-and-rack assembly, the rack guard, the control valve operating device, the control valve gear box, and the valve control motors are all mounted on one side of the engine.

The up-limit switches are located on the rack guard at the "out end" of the plunger stroke; the down-limit switches are located on the rack guard at the "in end" of the plunger stroke.

The operation of the elevator is controlled from either the platform pushbutton station or from the handwheel at the hangar-deck control station. When the "up-"control button is pressed at the platform station, it energizes the motors (valve control) and starts the valve control mechanism for the "up" travel of the platform. The valve control mechanism regulates the control and leveling valves, which in turn direct the flow of oil to and from the engine cylinder.

The valve control mechanism can be actuated either electrically or mechanically. Electrically, the valve is operated by the control motors which rotate the valve shaft. A section of the main shaft is threaded into an internally threaded bevel gear (fig. 7–12) in the control valve gear box. The speed of the bevel gear is controlled by the speed of the plunger travel by means of gearing to the traveling rack, while the screw-gear section of the main shaft rotates at the constant speed of the valve control motors. When the bevel gear is rotating at other

than shaft speed, it tends to push or pull the main shaft and valve pistons, opening or closing the control valve.

The push-and-pull motion of the control valve is counter to the action of the motors; when the motors tend to open the valve, the plunger motion tends to close the valve. Consequently, the valve seeks a position, while the elevator is running between terminals, which maintains the plunger speed at a constant ratio to the motor speed.

Hydraulic pressure forces the plunger the length of its stroke and, through the cable-and-sheave arrangement, lifts the elevator platform. The cam-and-rack assembly, as well as the limit-switch cam, travel along with the plunger. As the cam-and-rack assembly approaches the end of the plunger "out stroke," the "up" cam levels the arm on the control valve operating device, and gradually cuts off the flow of oil. As the limit-switch cam reaches the end of the out stroke, it trips the IRU–RUL limit switches (fig. 7–6) ; this causes the valve control motors to stop. The leveling valve remains slightly open and maintains pressure in the cylinder to keep the elevator platform at the flight deck.

When the "down"-control button is pressed at the platform-control station, it energizes the valve control motors and the valve control mechanism. As a result, the control valve opens. As the pressure is released, the weight of the platform forces the piston back into the cylinder, and the oil into the exhaust tank. As with the "up" travel of the platform, the cam-and-rack assembly and the limit-switch cam travel along with the plunger. As the end of the plunger "in stroke" is approached, the cam on the cam-and-rack assembly closes the control valve, the limit switches (IRD and RDL) are tripped, and the valve control motors are stopped.

HYDRAULIC POWER PLANT (ELEVATORS)

The pressure required for the operation of the hydraulic engine is produced in a closed hydraulic system

(fig. 7–7). The closed portion of the system consists of a pressure tank, an exhaust tank, the interconnecting main hydraulic pump and the main-pump strainer with valves, the engine cylinder, and the control and leveling valves. On some ships, however, the system contains two small main pumps in place of the one large pump. (The

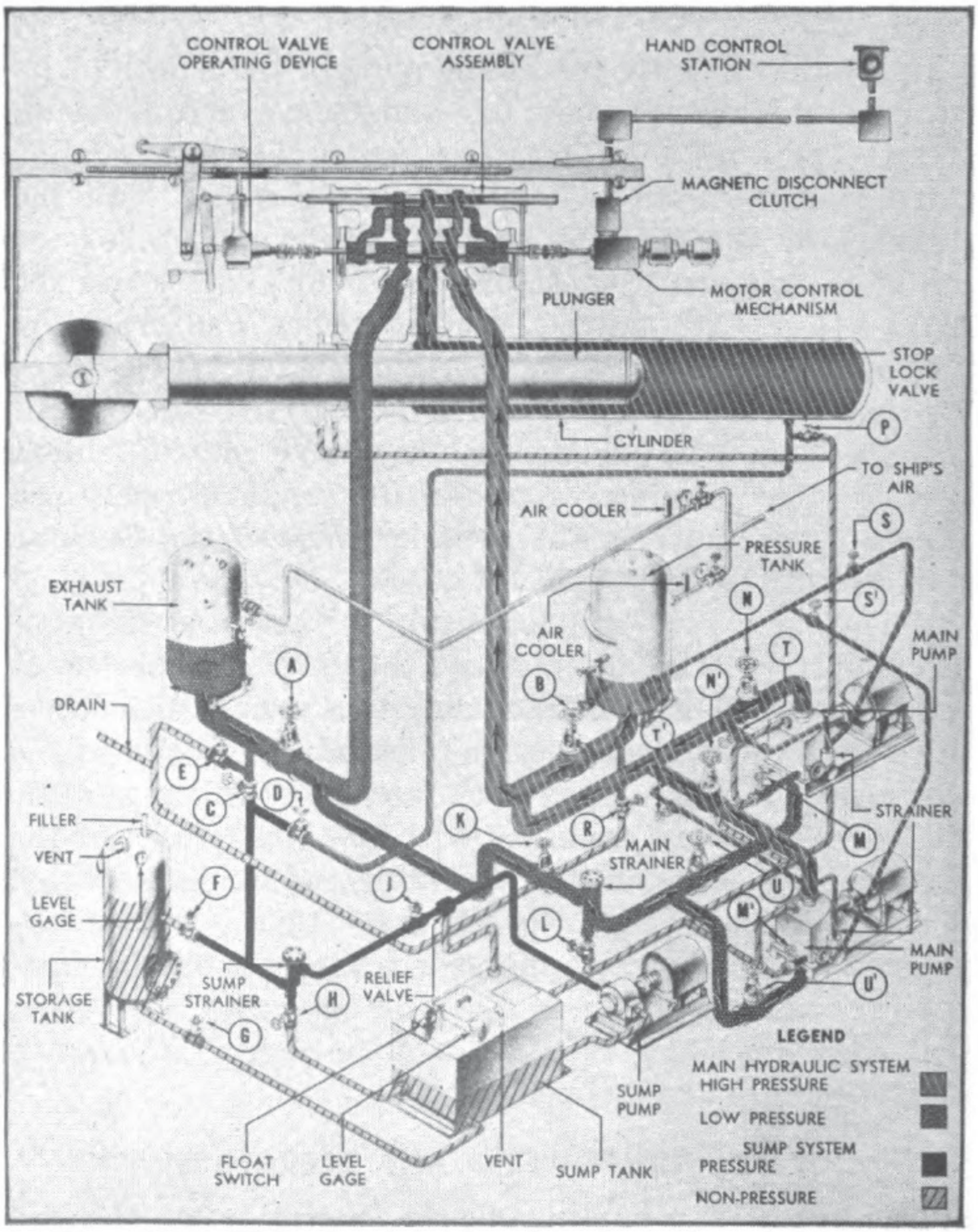
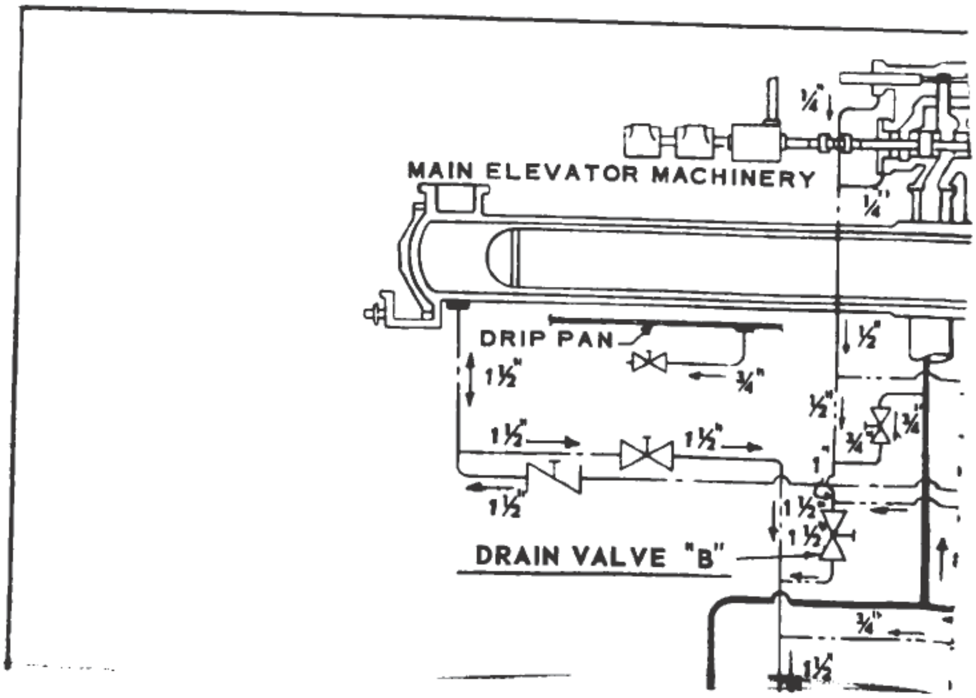


Figure 7–7.—Hydraulic system schematic (elevator going up).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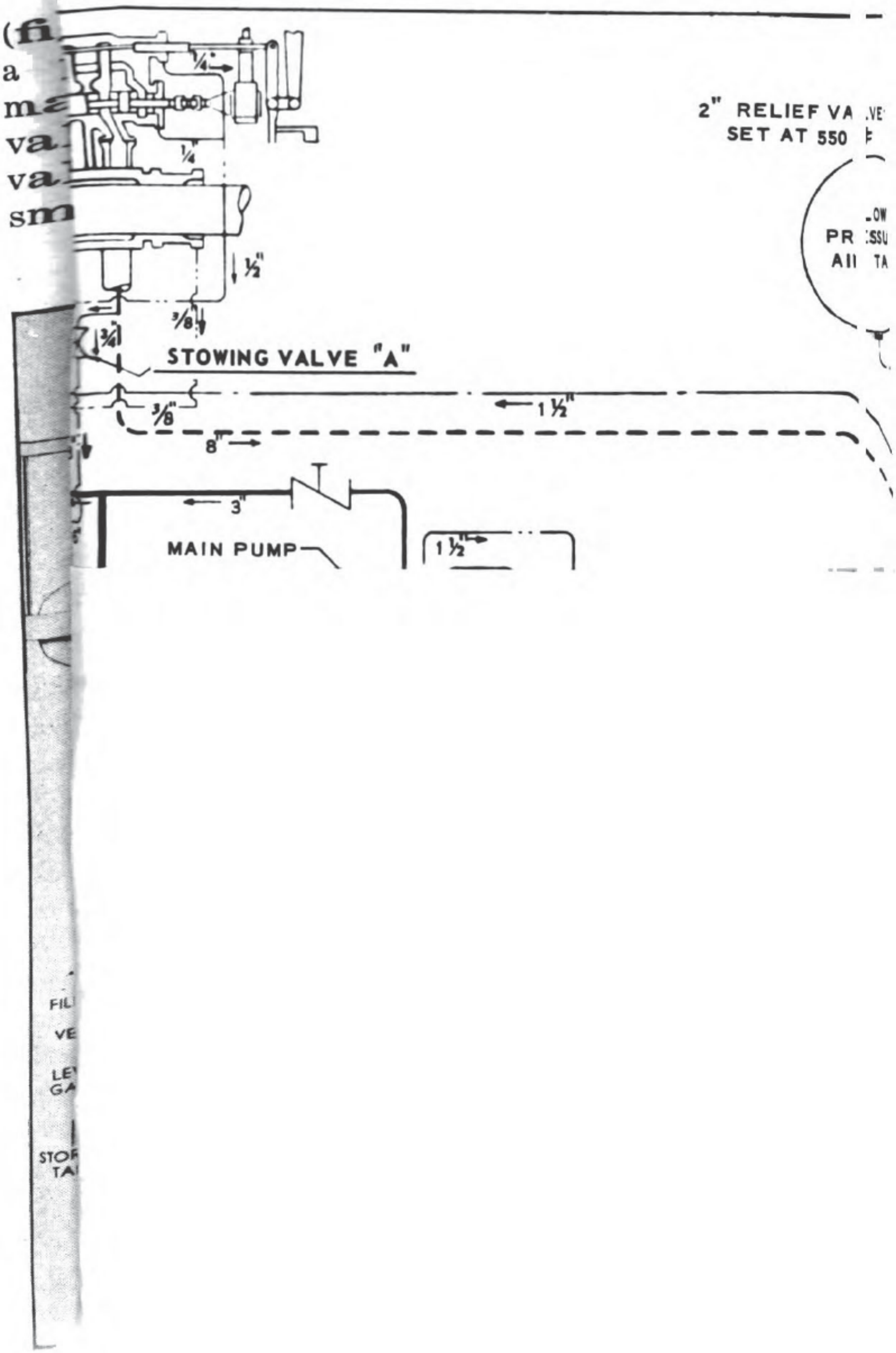

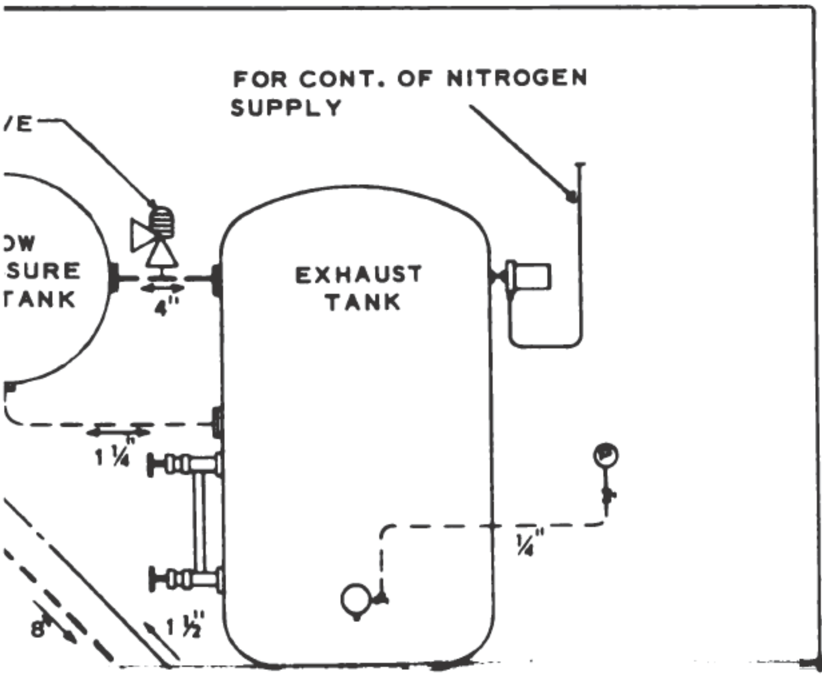

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main pumps are generally variable delivery high-pressure pumps.)

Figure 7–8 illustrates a hydraulic system consisting of four pumps, a high-pressure pipe and tank system, and a low-pressure or exhaust pipe and tank system. (This system is found on the CVA 19 and 34 class vessels.) Regardless of which hydraulic system is used, the principles of operation of all systems are the same. In addition to the closed portion of the hydraulic system (power plant), the storage tank, sump tank, sump pump and strainer, as well as the drain, fill, and bypass lines and valves, complete the elevator hydraulic system. The latter equipment is located in the engine and pump room.

The hydraulic system must be put into operation before the elevator platform can be operated. Each main pump is driven by an induction motor (squirrel cage), controlled by a semiautomatic across-the-line starter. Each starter is manually operated from a master switch located adjacent to the starter. The master switch includes "START," "STOP," and "EMERGENCY RUN" momentary contact switches.

The main pump draws oil from the exhaust tank, through a strainer (5-inch main oil strainer), and delivers it to the high-pressure tank (fig. 7–7). The oil, under pressure in the high-pressure tank, passes through the control valve into the engine cylinder, thus pushing the plunger the full length of its stroke. This causes the elevator platform to be raised to the flight deck.

When the control valve opens the valve port to the exhaust tank, the weight of the elevator pushes the plunger back into the plunger cylinder. Oil is forced out of the plunger cylinder through the control valve, and back into the exhaust tank, completing the hydraulic cycle, and lowering the elevator platform to the hangar deck.

The pressure tank contains air under pressure and sufficient fluid to cover the baffle plates in the bottom of the tanks, and to take care of the plunger displacement

and residual power requirement. Excessive pressure is removed by air relief valves in both the pressure and the exhaust tanks. Gage glasses on the pressure and exhaust tanks indicate the oil level. The initial air volume in the pressure and exhaust tanks is supplied from the ship's air supply.

By referring to the main hydraulic pump schematic, shown in figure 7–9, the operation of the pump can be studied by considering only one piston and cylinder. (The principles of operation are the same for both the large and the small pumps.)

A drive flange is mounted on the end of the drive shaft opposite the motor. A cylinder block is mounted freely within a swivel yoke and set with its ported end opposite the face of the drive flange. A universal link (connecting link) connects the center of the drive flange to the center of the cylinder block so that the cylinder rotates at the speed of the drive flange. Each of the piston rods is connected to the face of the drive flange by a joint.

The maximum angle between the face of the drive flange can be varied over 30° by adjusting the stroke regulator handwheel (fig. 7–9), mounted on the side of the pump. Since the length of the piston stroke is determined by the angle between the drive flange and the cylinder block, the setting of the stroke regulator handwheel limits the capacity of the pump to any predetermined rate from the maximum down to zero.

The stroke regulator handwheel controls the angular position of the swivel yoke and the cylinder block. The compensator operating spring, mounted within the compensator piston tube, pushes the yoke forward to the full stroke position. As the handwheel is turned to the "ON" stroke, the compensator spring forces the yoke and the cylinder into a position which will cause the pump to deliver oil into the hydraulic system at a rate determined by the amount of stroke permitted by the handwheel.

The compensator (fig. 7–10) is mounted on the side of the pump, opposite the handwheel, with the compensator

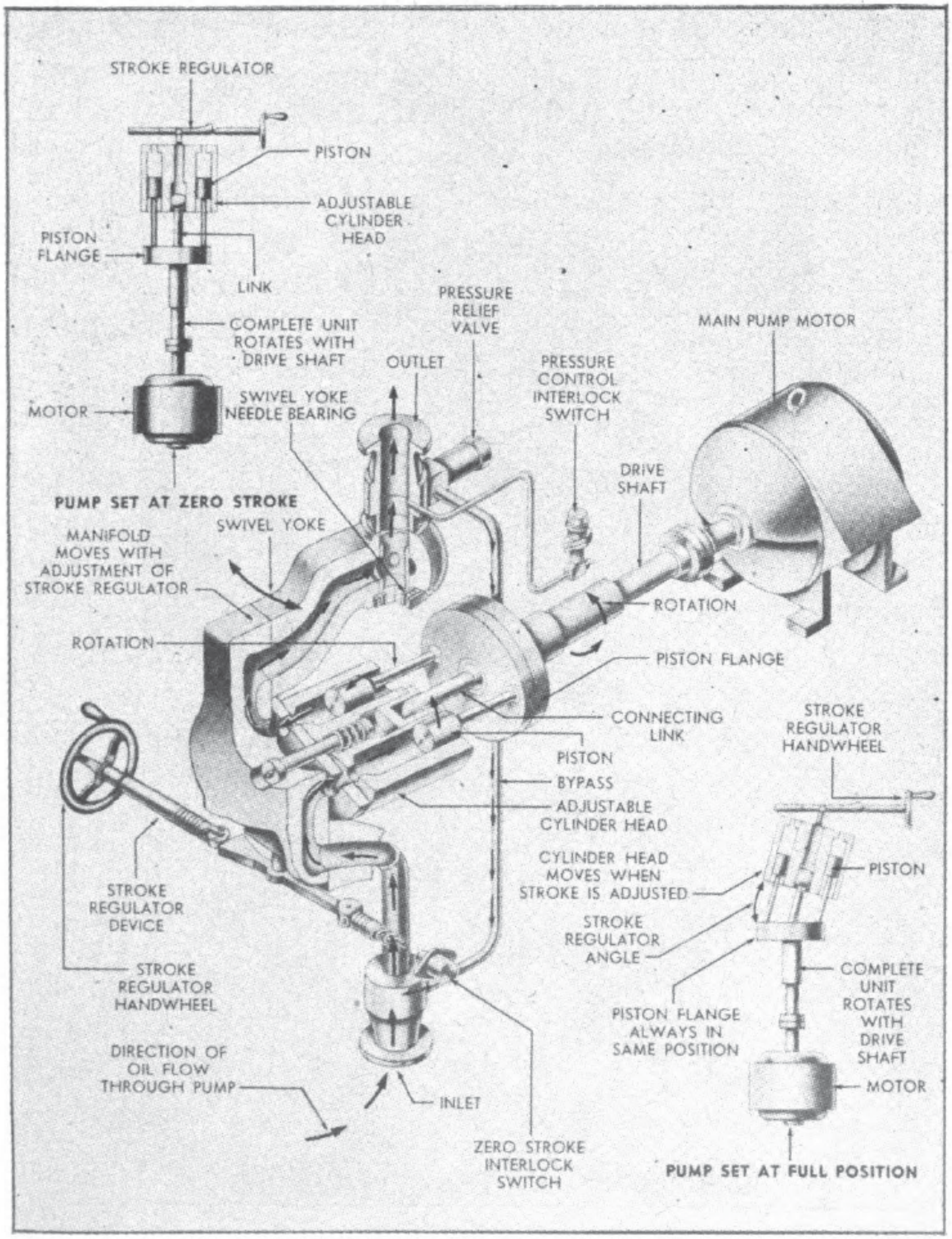


Figure 7–9.—Main hydraulic pump schematic.

control and the oil filter assembly above it. The compensator automatically sets the pump at zero stroke when the pressure in the high-pressure tank reaches 740 psi. Oil from the high-pressure tank passes through the filter assembly, the compensator control assembly, and into

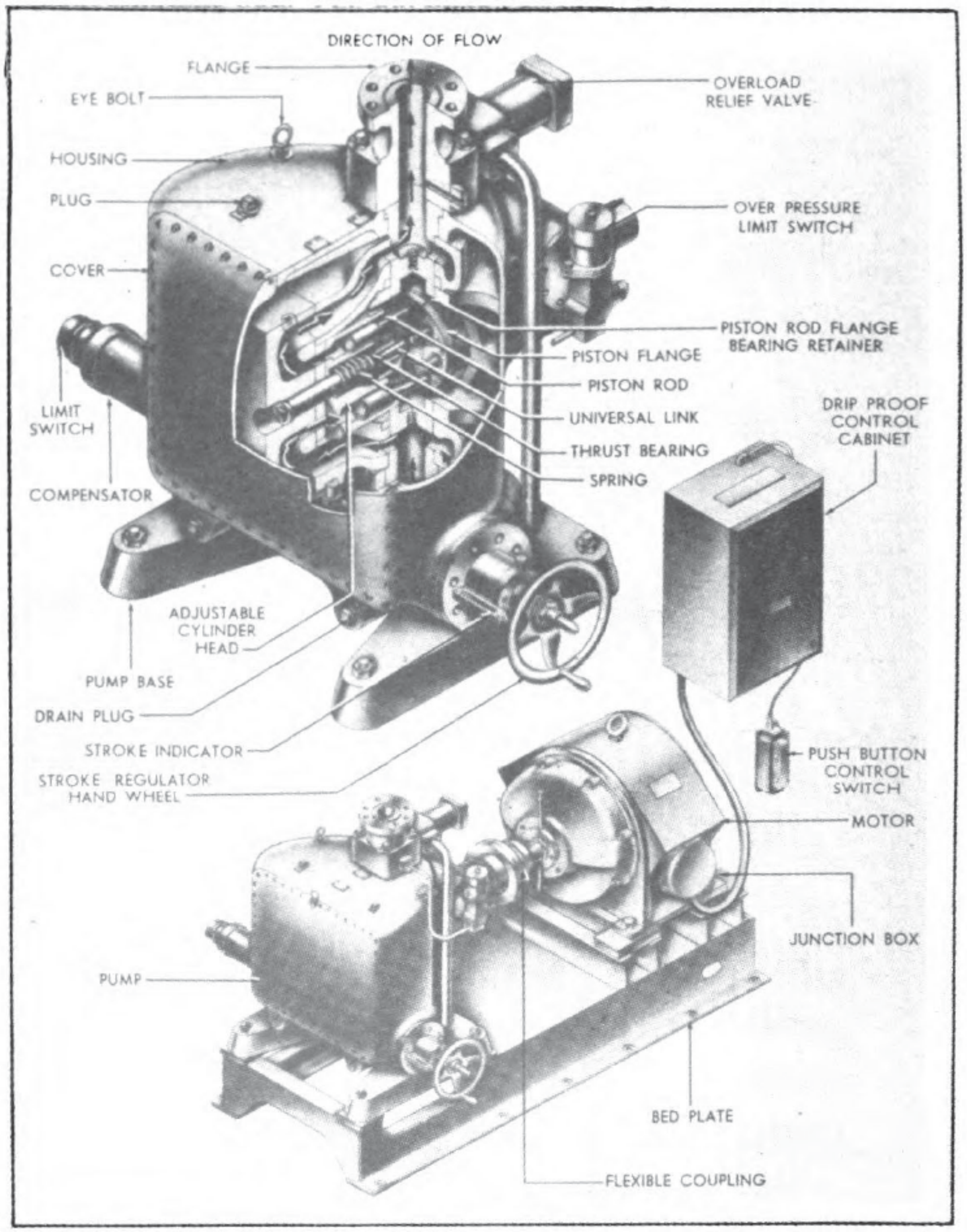


Figure 7–10.—Main hydraulic pump.

the compensator housing. The compensator control has an adjustment screw for setting the pressure at which the compensator piston operates. The screw is set for 740 psi. Consequently, when a pressure of 740 psi is reached, the resultant pressure is applied to the compensator and the pump returns to zero stroke.

The oil filter assembly is attached to the top of the compensator control. If the screen is clogged, a bypass relief valve, set at a differential pressure of 80-120 psi, is incorporated in the filter assembly to prevent damage to the oil filter elements.

An electric interlock switch, mounted on the compensator housing (fig. 7–10), prevents the pump motor from starting, but not from operating after it has started, when the stroke is at other than zero stroke. The interlock switch is normally held open by the action of the compensator operating switch rod until the compensator piston tube (moving to the zero stroke position) pushes against the interlock switch control rod, and closes the switch. This will permit the motor to be started by pressing the "START" button.

Another electric interlock switch, mounted near the pump inlet shaft, opens the motor circuit when the pressure at the pump exceeds 800 psi. An overload relief valve (fig. 7–10), on the pump, limits the differential pressure, between the intake and discharge sides of the pump, to 900 psi.

A main strainer prevents foreign matter from entering the pump. The strainer consists of fine-mesh wire cloth soldered inside of a perforated steel basket which is placed inside the strainer body. (The body has suitable openings for inlet, outlet, and draining lines.) The body cover is equipped with an air cock for venting and a thermometer well for taking oil temperature.

OIL SUPPLY AND SUMP SYSTEMS

The oil supply and sump systems for each hydraulic power plant provide means for (1) supplying or emptying oil to or from the hydraulic system, (2) returning oil leakage and drainage from the valve and pump units into the system, and (3) raising the platforms (in an emergency) to their upper terminals. The equipment of these systems includes an oil supply tank, a sump tank, two constant-delivery vane-type sump pumps and their

control equipment, a sump strainer, connecting piping, and valves (check and stop).

The OIL SUPPLY TANK (storage tank) stores oil for the filling and replenishment of the high-pressure oil system. It receives oil directly from the filling station on the hangar deck.

The SUMP TANK receives oil leakage or drainage from the control valves, the main strainer, and the pumps. It can also receive fresh oil directly from the oil supply tank. The sump tank is provided with a float switch set to start the sump pump at a predetermined oil level. The sump pump restores the oil in the sump tank to the pressure system. Occasionally more oil may be drawn from the storage tank to make up for leakage losses.

Each CONSTANT-DELIVERY SUMP PUMP is driven by a squirrel cage induction motor, controlled by an across-the-line starter that provides for either manual or automatic operation.

A MASTER SWITCH, located adjacent to each sump-pump starter, prevents the pump from operating when the switch is in the "STOP" position. This switch also controls the pump motor, during normal operation.

A MANUAL AUTOMATIC SELECTOR SWITCH, for each pump starter, selects the type of pump operation; manual from the master switch or automatic from the float switch.

A FLOAT SWITCH TRANSFER SWITCH interchanges the connections of the float switches to the sump-pump starters. The transfer switch should be operated daily in order to equalize the service on both pumps.

The 1½-inch SUMP OIL STRAINER, similar in design to the 5-inch basket-type main strainer, mentioned earlier in the chapter, is connected in the common delivery line (of the sump pump) to the exhaust tank.

In case of failure of the control valve, or the hydraulic power, after the gate valves have been operated properly, either one or both sump pumps may be used to raise the main and auxiliary elevators to their upper terminals.

For this emergency operation, oil is drawn from the sump tank and pumped directly into the cylinders. Oil is added, as required, by way of the drain pipe of the main strainer, to the sump tank either from the storage tank or the exhaust tank.

ELEVATOR CONTROL UNITS

The main control valve unit for each main elevator consists of the main valve, the leveling valve, the valve control motors, the screw shaft, the terminal stopping device, and the clutch brake. Figure 7–11 illustrates a control valve in neutral position and the initial setting of the valve.

The MAIN VALVE controls the flow of oil to and from the elevator cylinders. It is a differentially operated balanced piston valve, bypassed by a smaller piston-type leveling valve, mounted above the main valve. The latter unit consists of two valve assemblies, with copper gaskets used to seal the joints between them. The main valve also contains the main porting through which oil is directed by the three lands, or blocks, on the piston. The piston is maintained in equilibrium by the oil pressure on the two end blocks. The center block opens and closes the main port which connects to the engine cylinder.

The LEVELING VALVE contains the leveling port, through which oil is directed by the leveling valve piston. This valve also contains the bypass passage through which oil flows between the chambers within the main valve glands and the outer main valve balance blocks. It maintains the equilibrium of the main piston valve while the position of the piston is changing. Three air cocks are provided on top of the leveling valve in order to bleed any accumulated air from the hydraulic circuit.

The VALVE CONTROL MOTORS, connected through gears and a coupling to one end of the valve stem, are two tandem-mounted one-quarter-hp squirrel cage induction motors. When energized, the motors rotate the valve stem

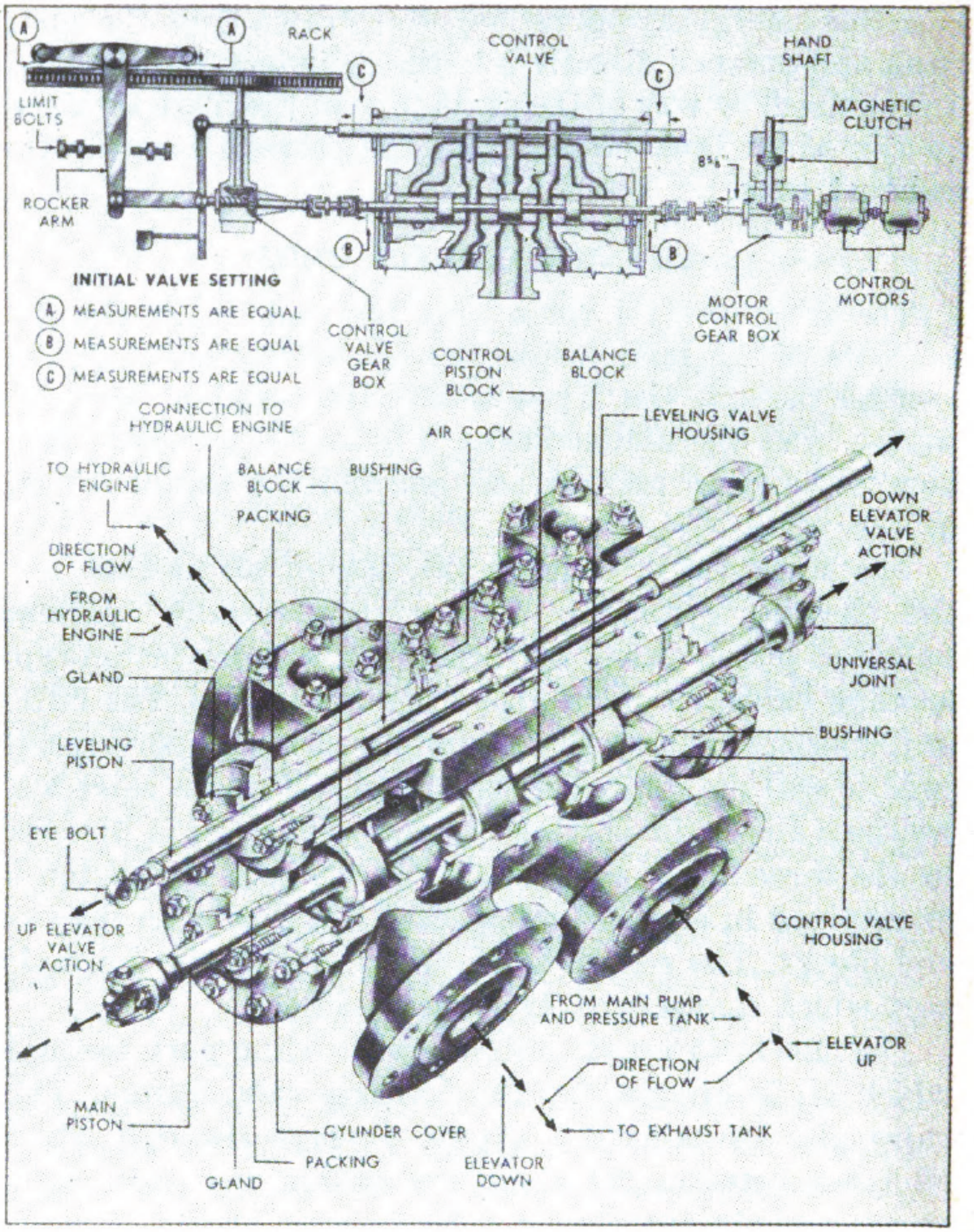


Figure 7–11.—Control valve assembly.

which causes the valve to open, as explained in the next paragraph.

The SCREW SHAFT is coupled to the other end of the valve stem. A long lead screw on the shaft is threaded into a sleeve which is fixed longitudinally and keyed to a spur gear (fig. 7–12), driven by the platform-control

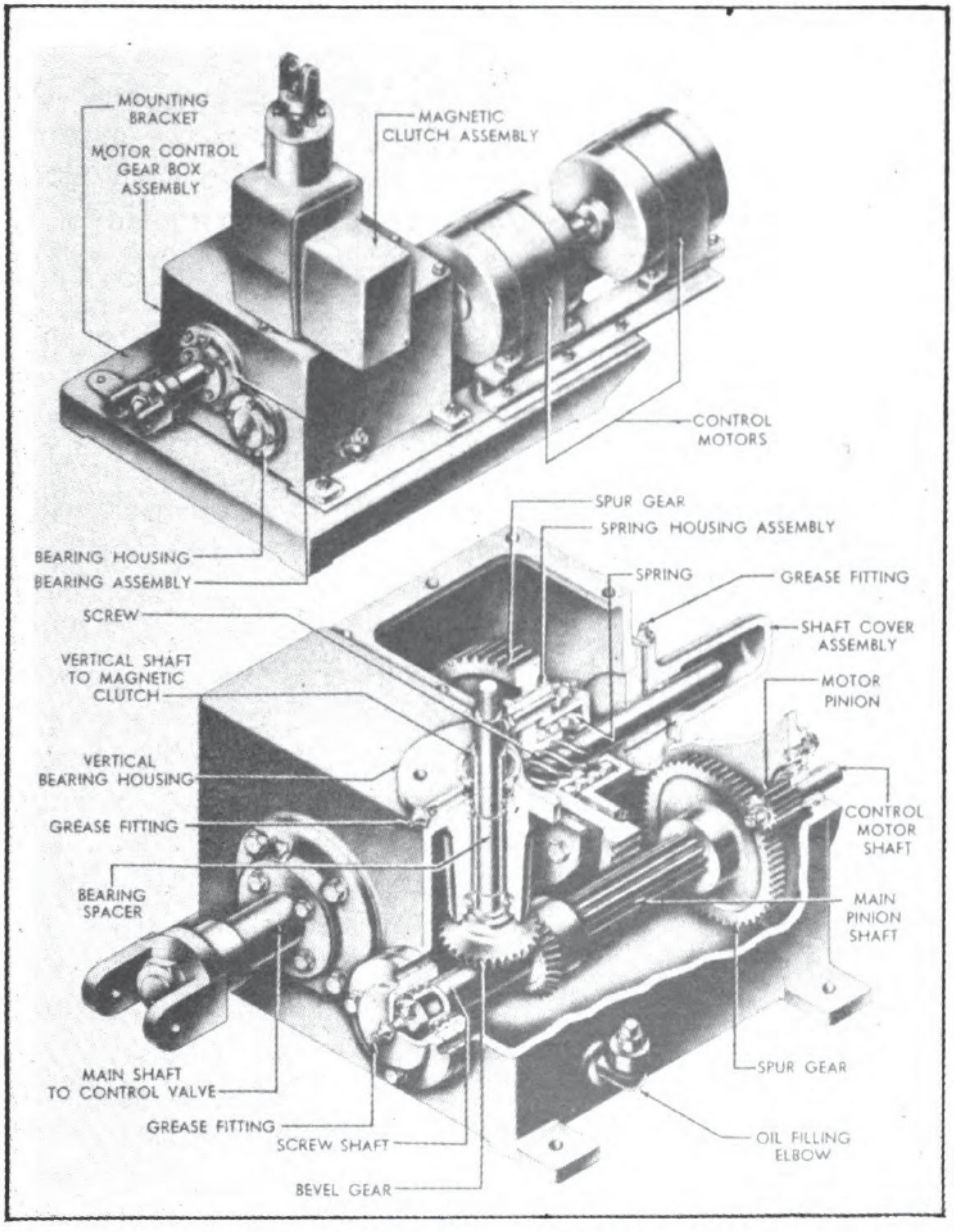


Figure 7–12.—Motor control gear box.

drive shafting. The turning of the screw in the sleeve causes a translatory motion of the shaft to open the control valve. As the platform moves in response to the valve opening, the sleeve is rotated by the platform-control drive in the same direction as the screw shaft. When the speed of both the screw shaft and the sleeve are the same,

there is no further opening of the valve. Thus, the valve is operated by differential rotation between the motor-driven shaft and the platform-driven sleeve, and the platform speed is controlled by the speed of the motors.

If the motors are now deenergized and the screw shaft rotation stopped, the platform-driven sleeve continues to turn and causes lateral motion of the screw shaft in the direction to close the valve. After the motors are deenergized, the time required to close the valve corresponds to an estimated distance of platform travel of approximately 3 feet, unless the platform is in the leveling zone.

The TERMINAL STOPPING DEVICE is the mechanical means of closing the control valve when the platform arrives at a terminal. The device consists of directional slow-down cams actuated by the platform-control drive shafting. The cams are set so that they rotate approximately 270° for full travel of the platform. As the elevator approaches approximately 40 inches from its terminal, the slow-down directional cams engage a lever arm which mechanically controls the position of the valve piston against the torque of the valve control motors, or manual control handle, in order to decelerate the platform properly and bring it to rest. The "up-" and "down-"directional cams are provided with slots which permit elevator slow-down adjustment.

A combination electric and mechanically operated CLUTCH BRAKE, mounted in the hand-control station directly above the main valve, disconnects (when disengaged) the hand-control shafting from the valve to the hangar deck while the elevator is being operated by electrical control, or by hand, from the valve station. The magnetic clutch (fig. 7–13) consists of a clutch housing, a clutch cone, a clutch cup, a clutch fork arm, and a magnet.

The clutch cup is mounted on the end of the vertical shaft extending from the top of the motor control gear box (fig. 7–12) ; the clutch housing is mounted on top of

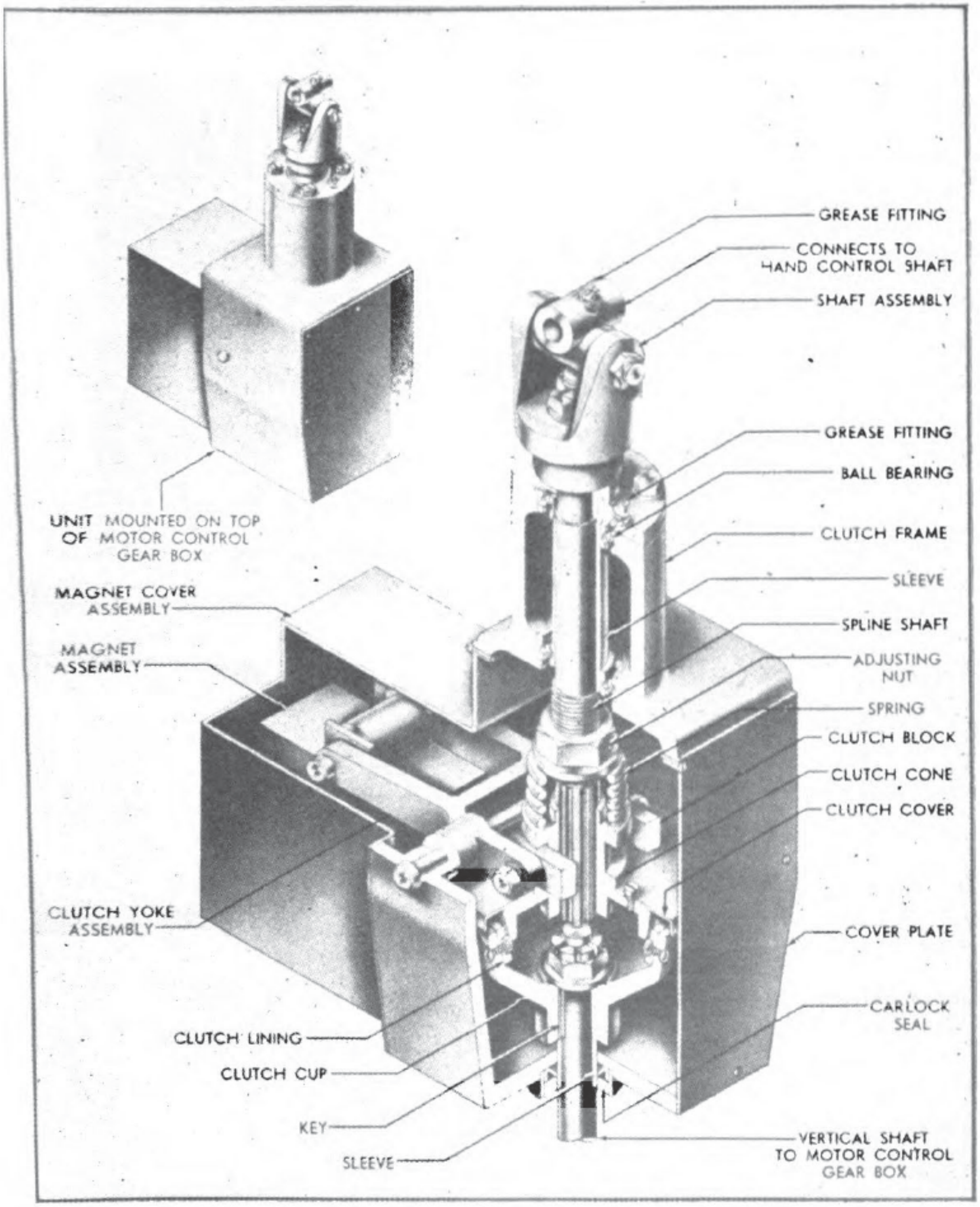


Figure 7–13.—Magnetic clutch.

the motor control gear box housing. The clutch cone, keyed to slide on the end of the hand-control shafting, is held tightly against the clutch cup by a spring on the shaft. A nut, above the spring, is used to adjust the tension of the spring for a tight fit of the cup and cone.

The clutch fork arm fits on the head of the cone with

rollers, and is attached to the clutch housing by a pivot pin. The other end is attached to a magnet that fits within a magnetic coil.

When power is applied to the valve control motors, the clutch magnet is energized. The magnet pulls down the end of the lever yoke arm and, against the pressure of the spring, lifts the clutch cone away from the clutch cup, thus disconnecting the hand-operated shafting from the motor control gear box. When the power is removed, the spring forces the clutch cone and cup together, thus connecting the hand shafting to the motor control gear box.

In the event of failure or damage to the platform-control drive shafting, a combination spline coupling is provided to disconnect the shafting from the control valve and to lock the platform-driven sleeve. With the shafting disconnected and the platform-driven sleeve locked against rotation, the control valve may be opened and closed by manual control, independent of the platform motion. The platform-control drive shafting can be uncoupled by removing the coupling bolts, and then lowering the bottom half of the coupling so that a hole in the flange engages a pin on the valve gear box.

When the platform-control drive shafting is disconnected, the elevator should be operated on manual control, and the emergency safety lever set to limit the elevator speed. (The safety lever trigger, when extended for emergency operation, engages a lever connected to the valve stem to limit the opening of the valve in either direction. A bolt locks the safety lever in either the extended or retracted position.)

When it becomes necessary to use the hand-control operating mechanism, the elevators should be operated cautiously, particularly the aft elevators; the electrical interlock switches of the main and auxiliary elevators, which prevent these elevators from colliding, are ineffective when manual control is used. The hand-control operating mechanism consists of the manual-control shafting

and two hand-control stations (one mounted at the valve assembly at the grating level, and the other mounted at the hangar-deck control station). The manual-control shafting consists of a system of hollow shafts, gears, and universal joints with necessary deck bearings. This shafting connects the hangar deck hand-control station to the control valve.

The HAND-CONTROL STATION AT THE HANGAR DECK is used for manual operation of the elevators in case of failure of the electrical mechanism. The manual-control operating handle is enclosed in a cast steel box and cover which should be locked when the station is not in use. When the hand-control station cover is unlocked and dropped down, it opens a normally closed interlock switch which, in turn, opens the electrical circuit and prevents the operation (electrical) of the elevator. Unlatching the operating handle by releasing the latch lever on the handle, from the fixed latch plate, allows rotation of the manual-control shafting from the hangar deck to the valve. If the manual-control handle is turned continuously, the valve for the corresponding direction of travel will open and the elevator will be kept in motion. (The speed of the elevator depends upon the speed with which the handle is turned. Valve and follow-up shafting operates the same as when under electrical control.)

The HAND-CONTROL STATION MOUNTED ON TOP OF THE CONTROL VALVE is for emergency use when either the manual control on the hangar deck or the manual-control shafting, between the hangar deck and the control valves, is severely damaged. This hand-control station is cased and locked similarly to the one at the hangar-deck control station. Opening of the cover opens a normally closed interlock switch, which prevents the possibility of operating the elevator electrically, and mechanically declutches the manual-control shafting from the valve to the hangar deck. In addition, the operating gear is automatically engaged to connect the operating handle to the valve operating gears.

As far as the aft auxiliary control-valve unit is concerned, it consists of the control valve, the valve control motor, and the necessary operating mechanism. The control valve regulates the flow of oil to and from the auxiliary elevator cylinders. The control valve is adjusted so that, when the platform is at a terminal, it remains slightly open to act as a leveling valve. The speed of the operation is regulated by an adjustment plug which governs the size of the valve bypass. Air vents are furnished on top of the valve to bleed accumulated air from the hydraulic circuit.

The valve control motor, connected through chain and sprocket to a valve drive pinion, engages a rack coupled to the valve stem. When energized, the motor transmits a translatory motion to the valve stem to cause the valve to open. Adjustable cams on the rack open normally closed limit switches which interrupt the motor circuit at the end of the valve opening stroke. The total rotation for full valve stroking is approximately one-half revolution. (Fig. 7–14 illustrates the operational cycle of a typical auxiliary control valve.) The opening stroke of the valve is limited by a mechanical positive stop. Bolts, which engage the positive stops, permit the adjustment of the valve stroke and the operating speed of the elevator.

The terminal stopping device functions to close the valve when the platform arrives at a terminal. It is so adjusted as to allow the valve to remain slightly open for leveling and maintaining the car level with the deck, against leakage. The device consists of a lug, driven by the auxiliary elevator platform control drive, to which it is connected by gears, chains, and sprockets. The lug operates cams on the motor-driven sprocket. As the platform-driven lug engages the cams, it operates the valve drive pinion to close the valve to leveling position.

The auxiliary elevator hand-control operating mechanism consists of the hand-control station, at the main

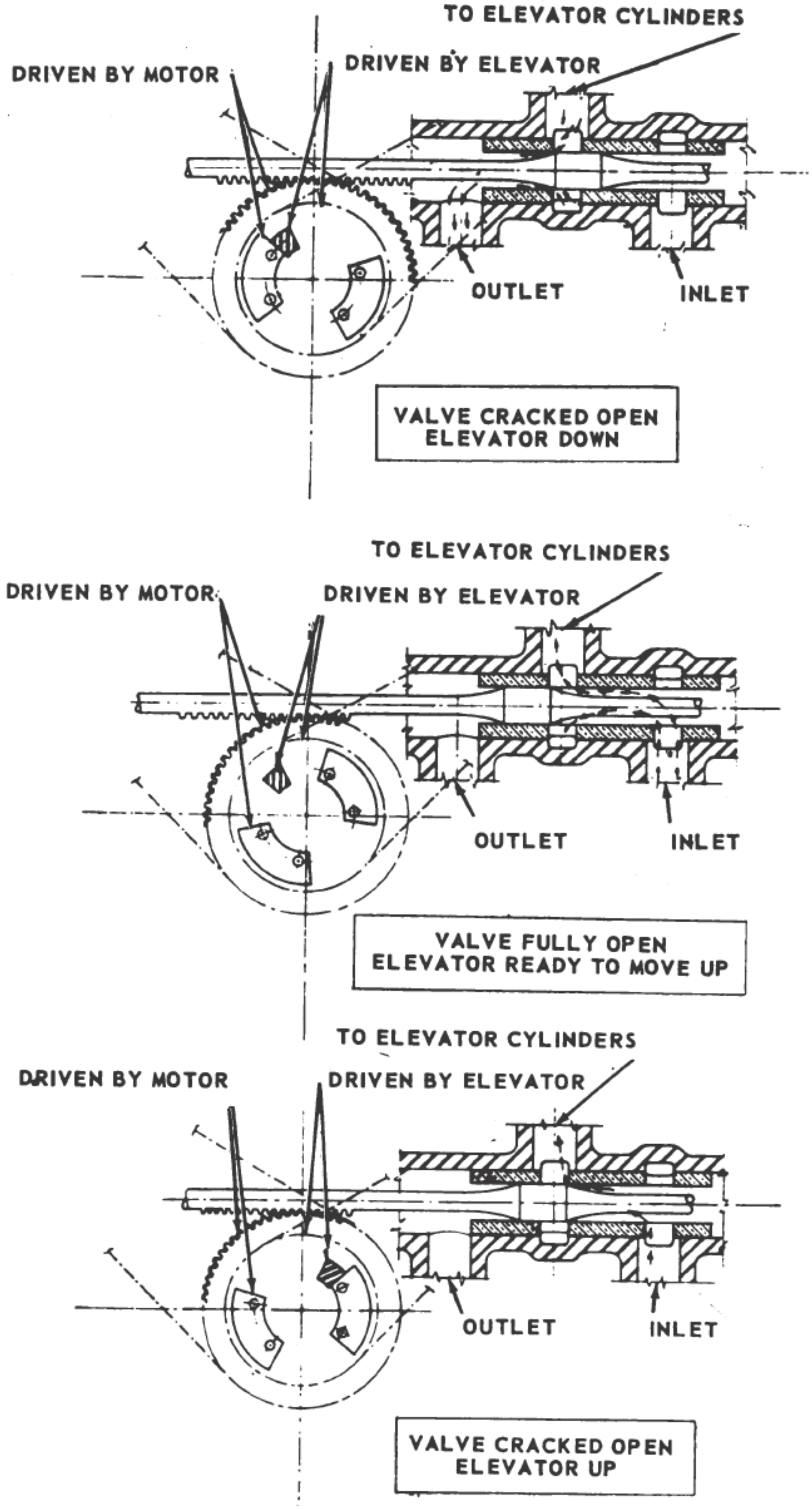


Figure 7–14.—Operational cycle of an auxiliary elevator control valve.

valve, together with the necessary gearing to open and close the valve.

The hand-control station, located at the auxiliary valve, is enclosed and locked similarly to the main elevator hand-control stations. Opening the box cover opens a normally closed interlock switch which, in turn, opens the electrical circuit to the valve torque motor, preventing electrical operation of the elevator. Turning the operating handle, geared to the valve drive pinion shaft, opens the valve for the desired direction of travel. The opening stroke of the valve is limited, and recentering of the valve is accomplished in the same manner as previously described in the paragraphs dealing with the aft auxiliary control valve unit.

OPERATION OF MAIN ELEVATORS

Elevator operation may be directed and controlled from the platform-control station (fig. 7–15) by the pushbutton, or at the hangar-deck control station (fig. 7–16) by the handwheel. The hangar-deck control station is the master over all operations. At this station, the elevator may be operated by hand or, by holding the master switch in the "ON" position, it may permit operation of the elevator by the pushbutton station on the platform. (The electrical interlock at this station prevents the use of the platform-control station when the elevator is on hand control.)

The operation described below is for the aft main elevator of carriers equipped with one auxiliary and two main elevators. The operation for the forward main elevator, however, is the same except for the omission of all references to the auxiliary elevator.

Before proceeding with the operation of the main elevators, let us assume that both the main and auxiliary elevators are standing at their respective lower terminals ready for operation. In this case, the following conditions exist:

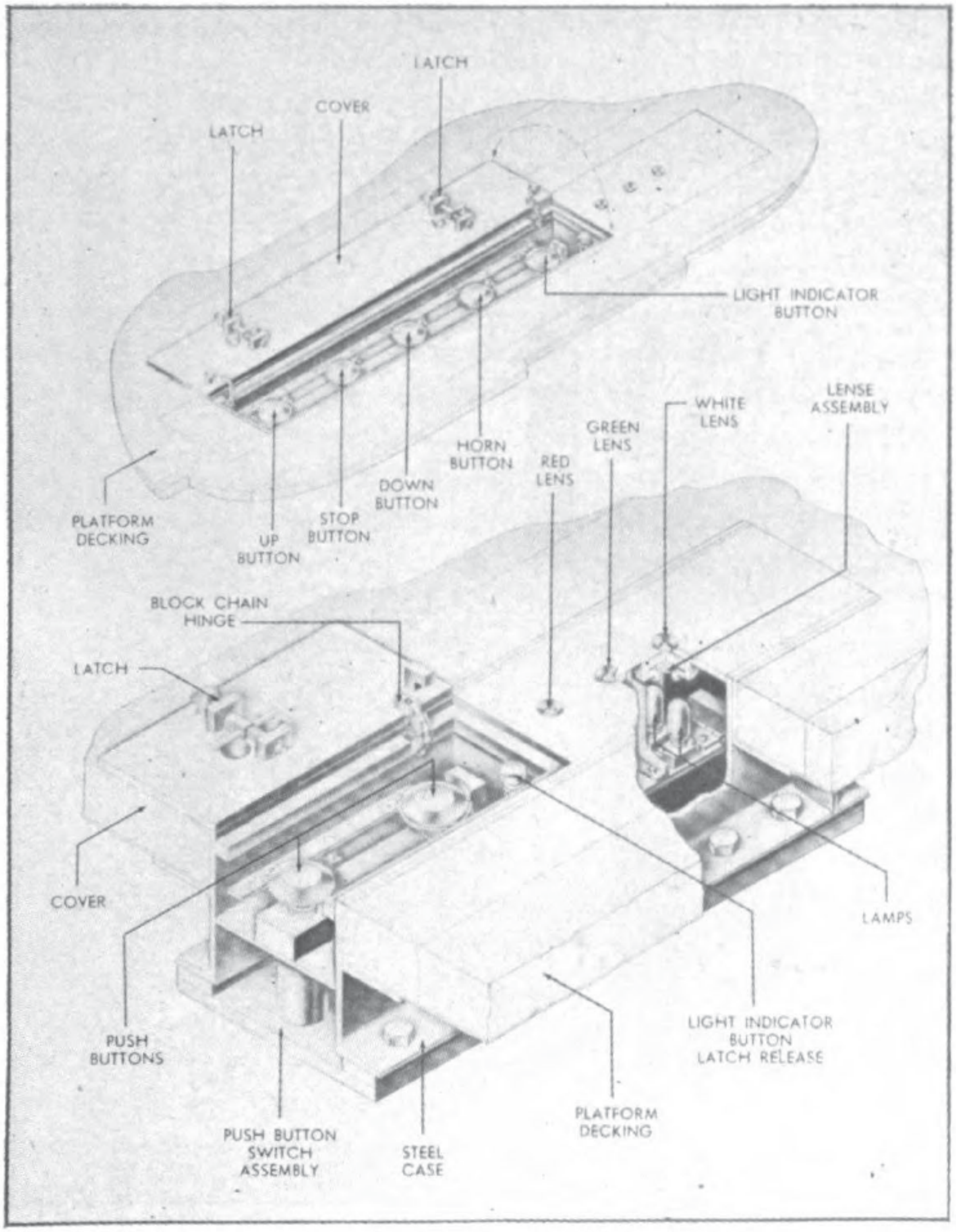


Figure 7–15.—Platform-control station.

1. The control and signal light switches at the hangar deck are in the "ON" position.
2. The power supply circuits are closed.
3. The pump-running interlock switches are closed.
4. The hand-control interlock switches are closed.
5. The lock bar interlock switches are closed.

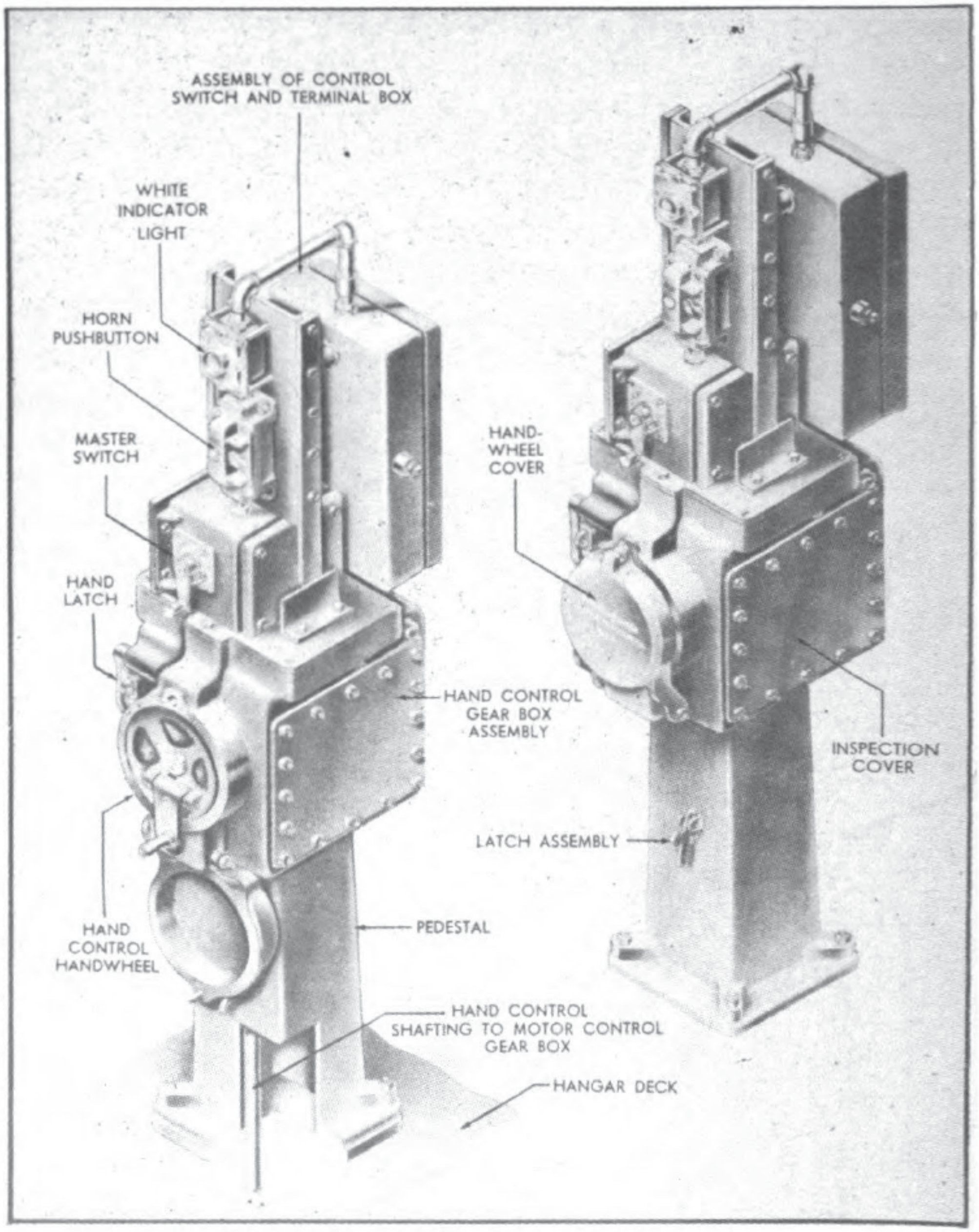


Figure 7-16.—Hangar-deck control station.

6. The entrapped air has been bled from the cylinder, the control valve, the strainer, and the pressure piping.

To operate the main elevator, under the above conditions, the elevator "UP" button is momentarily pressed; this connects the valve control motors to the line and

energizes the clutch brake. Then the clutch brake disengages the hand-control shafting and the valve motors start at full torque to open the main valve for the "UP" travel. The opening stroke of the valve admits oil from the pressure tank to the operating cylinder of the elevator. The stroke is completed when the platform speed is synchronized with the motor speed as described in the section dealing with elevator control units.

When the main elevator reaches a point 6 feet above the hangar deck, the auxiliary elevator interlock switch closes and, if desired, the auxiliary elevator can be operated. Remember that the operation of the auxiliary elevator is entirely independent of the main elevators, except for the interlock and the interference switches which prevent collision of the elevators.

When the "up-"traveling main elevator is approximately 40 inches from the flight deck, it opens the initial "up-"limit switch and reduces the torque delivered to the valve stem shaft by disconnecting one valve control motor and inserting resistance in the circuit of the other valve control motor. Then the terminal stopping device, driven by the platform through the followup shafting, mechanically closes the main valve which overcomes the reduced torque of the valve control motor that tends to keep the valve open. The elevator slows down.

When the elevator is one-half inch from the terminal, the final "up-"limit switch opens to disconnect the other control motor and apply the clutch brake. At this point, the main valve has been closed but the leveling valve is open sufficiently to bring, as well as to maintain, the platform level with the flight deck.

The "down" operation is similar to the "up" operation, except that the down switches and contactors are operated. In addition, the control valve is open to allow oil from the elevator cylinders to pass to the exhaust tank. To prevent the main elevator from colliding with the auxiliary elevator, an interference switch is provided to stop the descending main elevator at a predetermined

point (about 9 feet below the flight deck), unless the auxiliary elevator is at its lower terminal.

OPERATION OF AFT AUXILIARY ELEVATORS

As you know, the operation of the aft auxiliary elevator is initiated either electrically from the hangar-deck control station or manually from a manual-control station at the valve mechanism.

Before proceeding with a description of the operation of the auxiliary elevator, let us assume that the auxiliary elevator is at its lower terminal and the main elevator a sufficient distance above the hangar deck to allow the auxiliary elevator interlock switch to be closed.

To raise the elevator (particularly on CVS installations), momentarily press the "UP" button. The valve motor is energized and starts to open the valve for "up" travel. The opening stroke of the valve admits oil from the pressure tank to the auxiliary elevator cylinders. An "up" cam on the extended valve stem or rack opens the limit switch which interrupts the circuit to the motor at the end of the valve stroke. The stroke of the valve is limited by mechanical stops.

As the platform approaches its destined landing, the terminal stopping device automatically brings the valve to a practically closed position. (The slight valve opening serves to bring, as well as maintain, the elevator level with the flight deck.)

The lowering operation is similar to the raising operation, except that the "down" contactor and "down" switches are operative, and the valve admits oil from the auxiliary elevator cylinders to the exhaust tank. No means are provided for stopping the auxiliary elevator between terminals.

As the auxiliary platform leaves its lower terminal, an interference switch opens to prevent the "down" operation of the main elevator, below the ventilating position (about 9 feet below the flight deck).

When the aft main elevator is traveling in the "down"

direction, an interlock contact on the aft main elevator controller opens and prevents the auxiliary elevator from being raised.

MAINTENANCE OF ELEVATOR EQUIPMENT

As an MM2, you will be required to know how to renew packing on elevators and on hydraulic steering gears. In addition, you will be required to know how to change seals and gaskets on hydraulic equipment. Detailed instructions concerning the maintenance of a specific unit can be found in the appropriate manufacturer's technical manual; however, the general information which follows will also be helpful.

Replacing the Hydraulic Engine Cylinder Packing

As the plunger moves in and out of the cylinder, the hydraulic engine cylinder packing confines the pressure in the cylinder and prevents leakage of oil. To prevent leakage, the cylinder gland nuts must be tightened periodically. If the cylinder gland nuts have been tightened, and the packing continues to leak excessively, examine the packing for wear or damage. A worn or damaged packing must be replaced with a new packing; figure 7-17 illustrates a hydraulic system schematic for replacing the engine cylinder packing.

To replace the packing, proceed as follows:

1. Lower the platform to the hangar deck. Close the pressure tank valve (*B*), the exhaust tank valve (*A*), and the strainer valve (*K*).
2. Reduce the pressure, and drain the oil from the cylinder by opening the engine drain lock stop valve (*P*) and the cylinder air-cocks. This will cause oil to drain from the cylinder into the sump tank. (To avoid overflow of oil from the sump tank, energize the sump-pump controller to run the pump motor.)
3. Remove the gland nuts and pull the gland out (fig. 7-18).

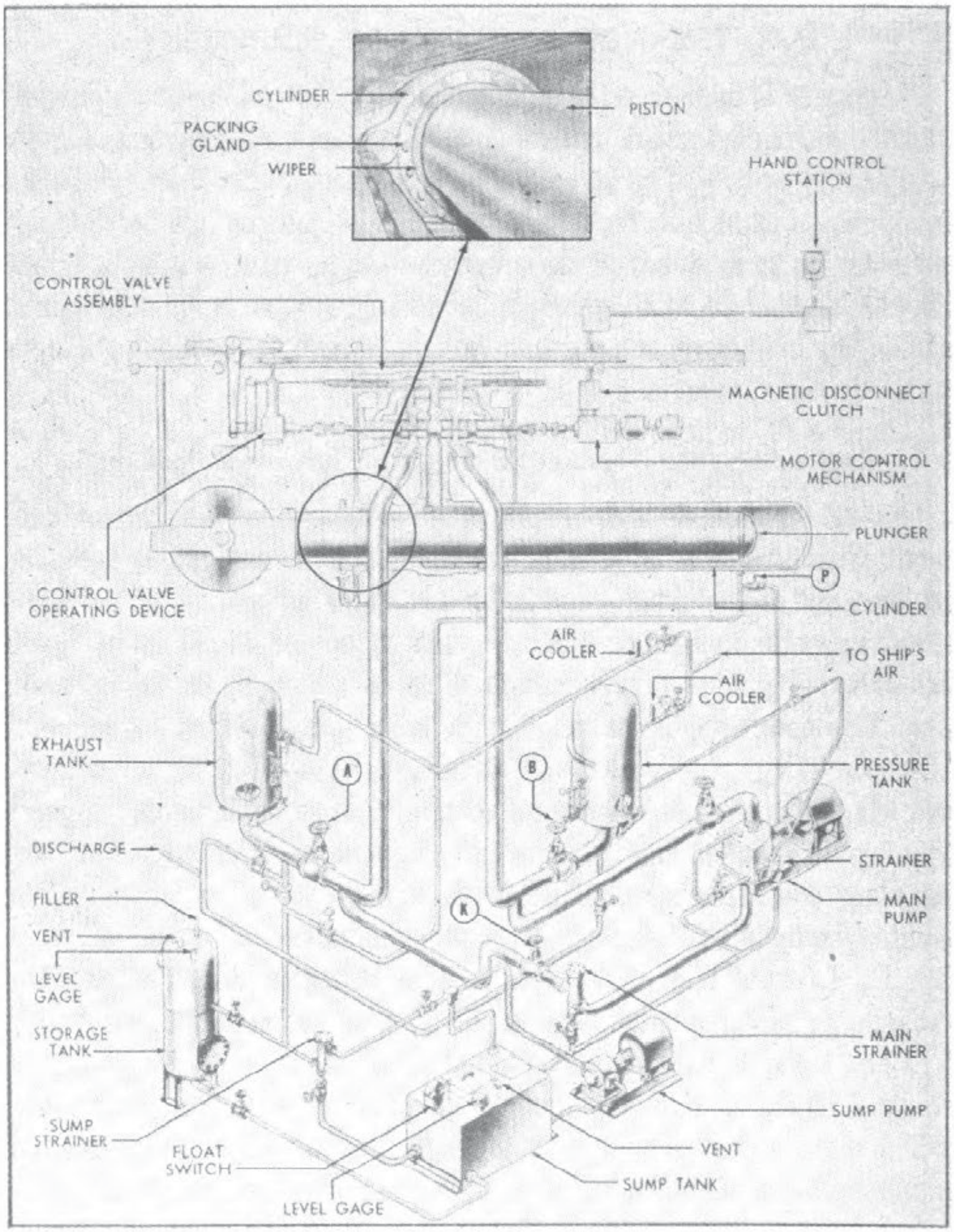


Figure 7–17.—Hydraulic system schematic for replacing the engine cylinder packing.

4. Remove the old packing rings until a steady stream of oil flows into the drip pan under the engine. This oil should be directed, through the drip pan drain, into the sump tank. When the cylinder has been drained of oil, remove the remainder of the old packing.
5. Replace the packing with a new set of rings. The splits in the packing rings should be staggered around so that no two splits in the rings come together. (Figs. 7–18b and c illustrate how a packing is removed and replaced with a new one.)
6. Replace the gland and the gland nuts. Extreme

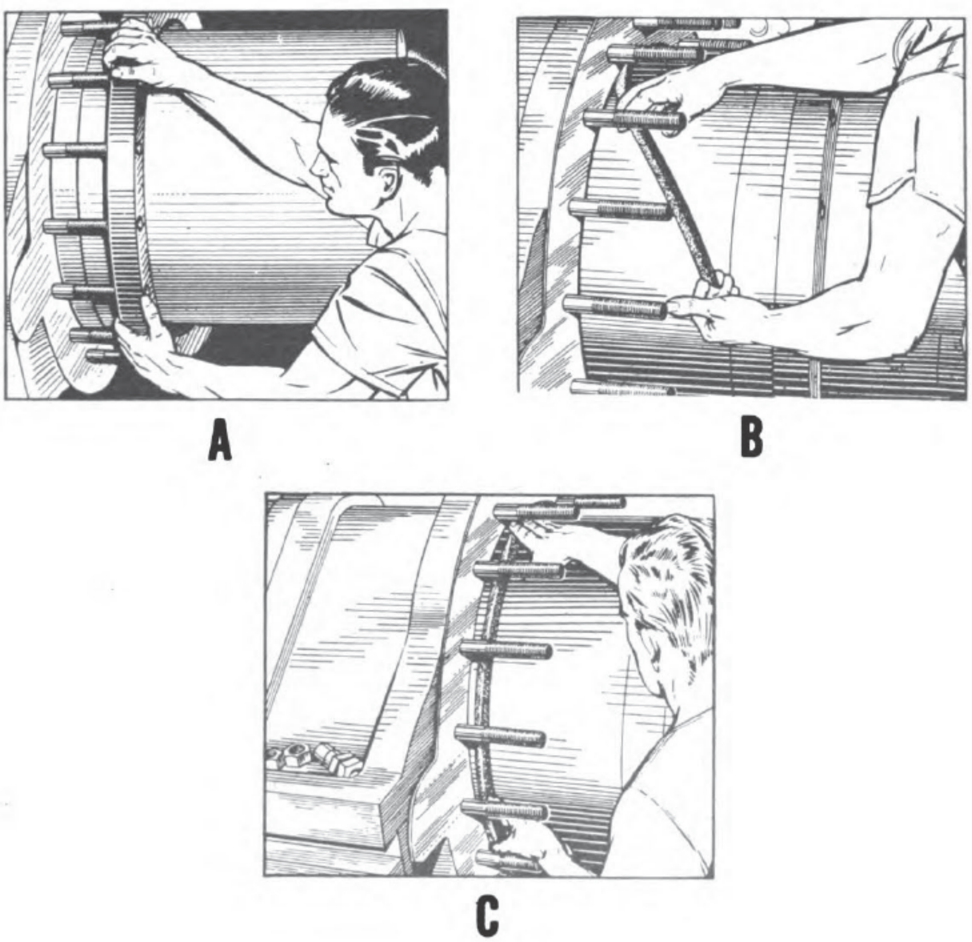


Figure 7–18.—(a) Removing cylinder packing gland, (b) removing old packing, and (c) replacing packing.

care must be taken to pull down the nuts evenly and only to the point where the nuts are snug.

7. Close the engine drain lock stop valve (*P* of fig. 7–17), and open the pressure tank valve (*B*). Open the control valve slightly by rotating the hangar-deck control wheel in a clockwise direction until oil flows from the engine air-cocks.
8. Close the control valve by rotating the hand control wheel, of the hangar deck, counterclockwise as far as possible; then open the exhaust tank valve (*A*).
9. Tighten the packing gland nuts evenly until the oil is only a few drops per second. Lock the nuts with the jam nuts. Do not tighten the packing too much. (Due to the "V" cross section of the packing, the pressure within the cylinder helps to seal the packing and provides a satisfactory seal without excessive gland pressure.)
10. Bleed all the air from the cylinder, the control valve, the strainers, and the pressure lines.
11. Raise the platform to the flight deck and lock it in place. Check the tank oil levels and pressures before replacing the elevator in service. An oil seal is provided for wiping the plunger of foreign material on the "in stroke." The seal is split and can be removed after sliding off the cover plate.

Replacing the Valve Piston Packing

To determine the condition of the valve stem packing, make periodic inspections of the sump connections from the valve to determine the tightness of the valve stem packing. Excessive leakage results in a loss of pressure in the pressure tank. To tighten the valve stem packing, remove the packing glands and one one-sixteenth-inch washer from each stud. Replace the gland and pull up tight against the washers. Figure 7–19 illustrates a hydraulic system schematic for replacing the valve piston packing.

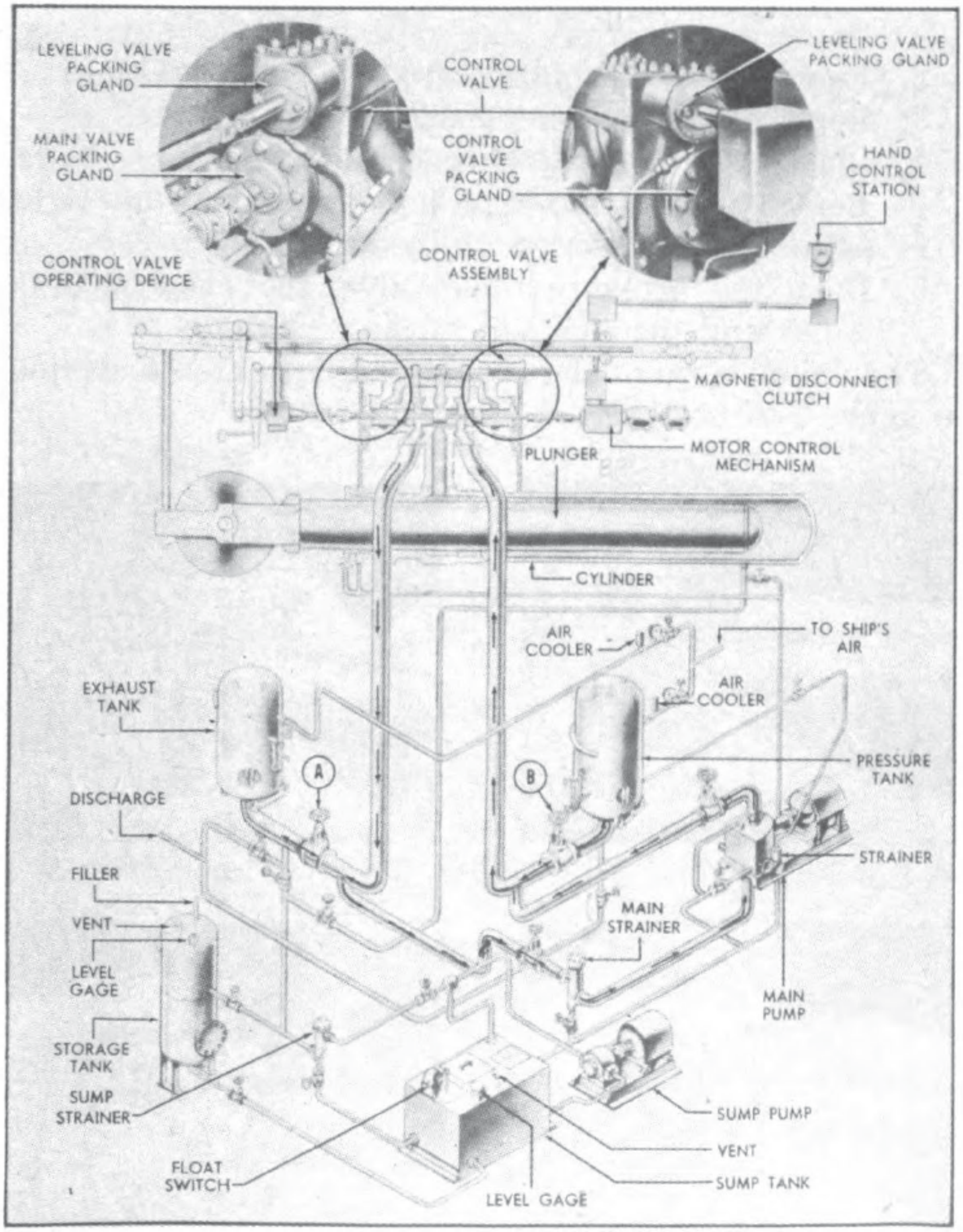


Figure 7–19.—Hydraulic system schematic for replacing the valve piston packing.

In case of excessive oil leakage, replace the valve piston packing as follows:

1. With the platform locked at the flight deck, close the pressure tank valve, the exhaust tank valve, and the strainer valve.
2. Remove the packing gland and the old packing.
3. Replace the old packing with a new packing.
4. Place three-eighth-inch packing washers on studs. Replace the glands and pull the glands up tight against the washers with the nuts.
5. Open the pressure tank valve, the exhaust tank valve, and the strainer valve.

The major steps of the above procedure are illustrated in figure 7–20 (a-d).

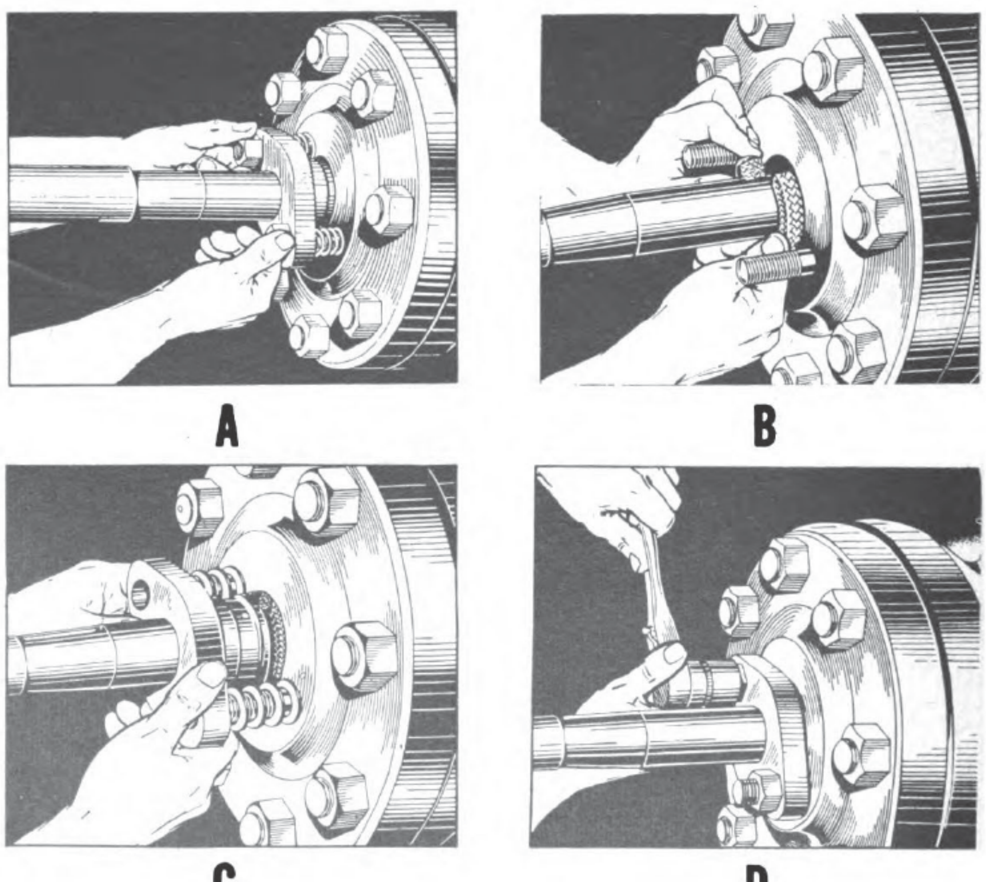
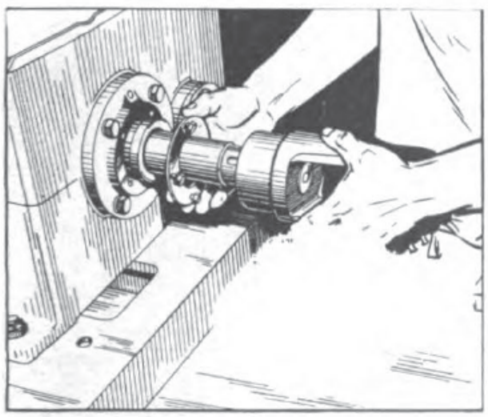


Figure 7–20.—(a) Removing valve piston packing gland, (b) replacing gland packing, (c) replacing packing gland and washers, (d) tightening packing gland nuts.

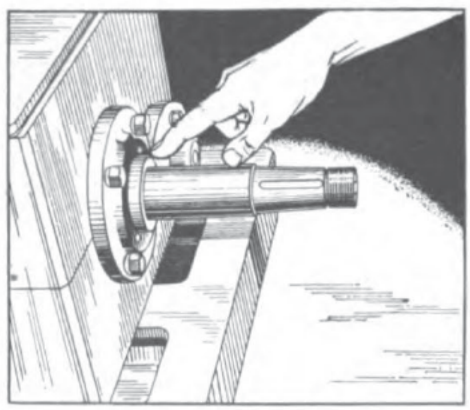
Replacing Main Shaft Oil Seals

When the main shaft oil seals become worn or damaged and cause excessive oil leakage, replace the seals as follows:

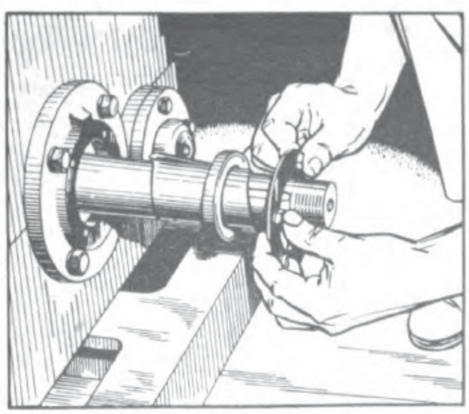
1. Disconnect the universal joint from the main shaft by removing the bolt.
2. Shove the main shaft toward the motors.
3. Remove the fork and the plate (fig. 7–21a).
4. Remove the old seal and replace it with a new seal (fig. 7–21b).
5. Reassemble the seals with the plate, fork, and universal joint (fig. 7–21c).



A



B



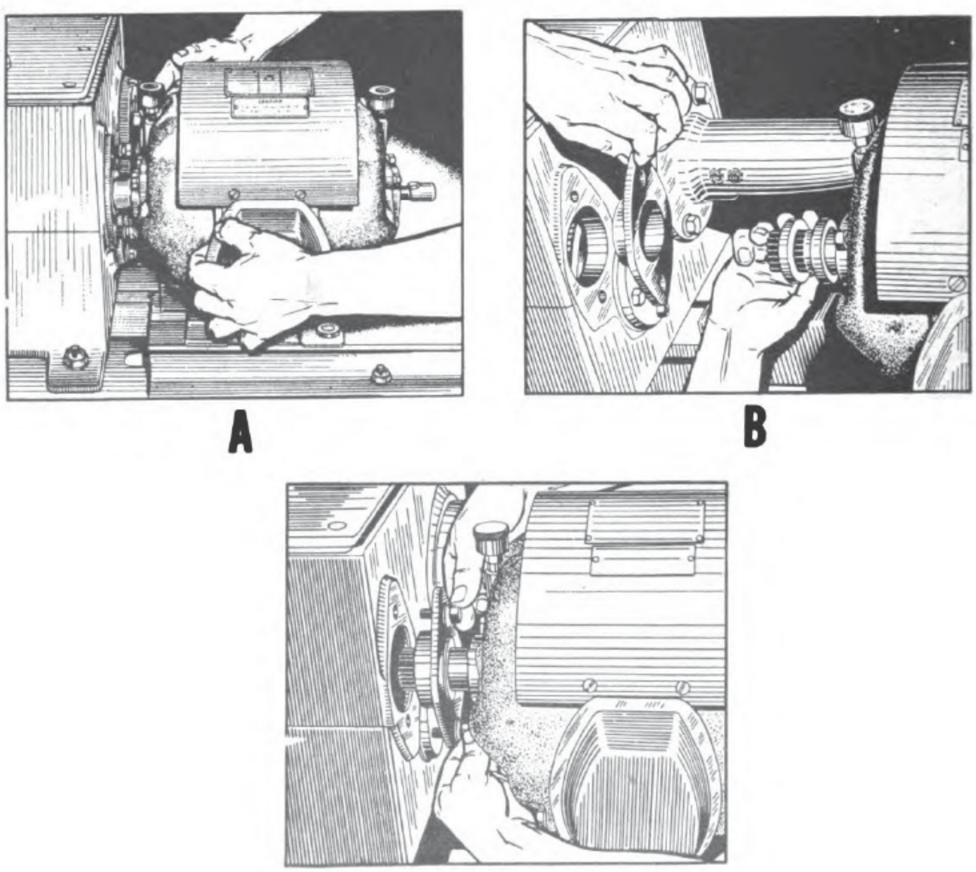
C

Figure 7–21.—(a) Removing fork and plate, (b) removing oil seal, and (c) reassembling oil seal and plate.

Replacing Motor Shaft Oil Seals

To determine the condition of the motor pinion assembly and associated oil seals, make periodic inspections for excessive leakage. If it becomes necessary to replace the motor shaft oil seals, proceed as follows:

1. While supporting the motors, remove the bolts fastening the motor blocking to the mounting bracket.
2. Pull the motors horizontally away from the gear box until the pinion on the motor shaft is clear of the gear box (fig. 7–22a).
3. Remove the old seals and replace them with new seals (fig. 7–22b).
4. Return the motor pinion into the gear box, and bolt



A B C

Figure 7–22.—(a) Pulling motors, (b) replacing oil seals, and (c) returning motor pinion into gear box.

the motor blocking, or frames, into place (fig. 7-21c).

Cleaning Main- and Sump-Pump Oil Strainers

The main-pump oil strainers should be cleaned shortly after the hydraulic system has been filled with oil, or after repair work has been completed. (It is possible that foreign matter, such as dirt, metal chips, and filings may have entered the system.) To clean a main-pump oil strainer, proceed as follows:

1. Close the strainer intake (inlet) valve and the main-pump suction valve.

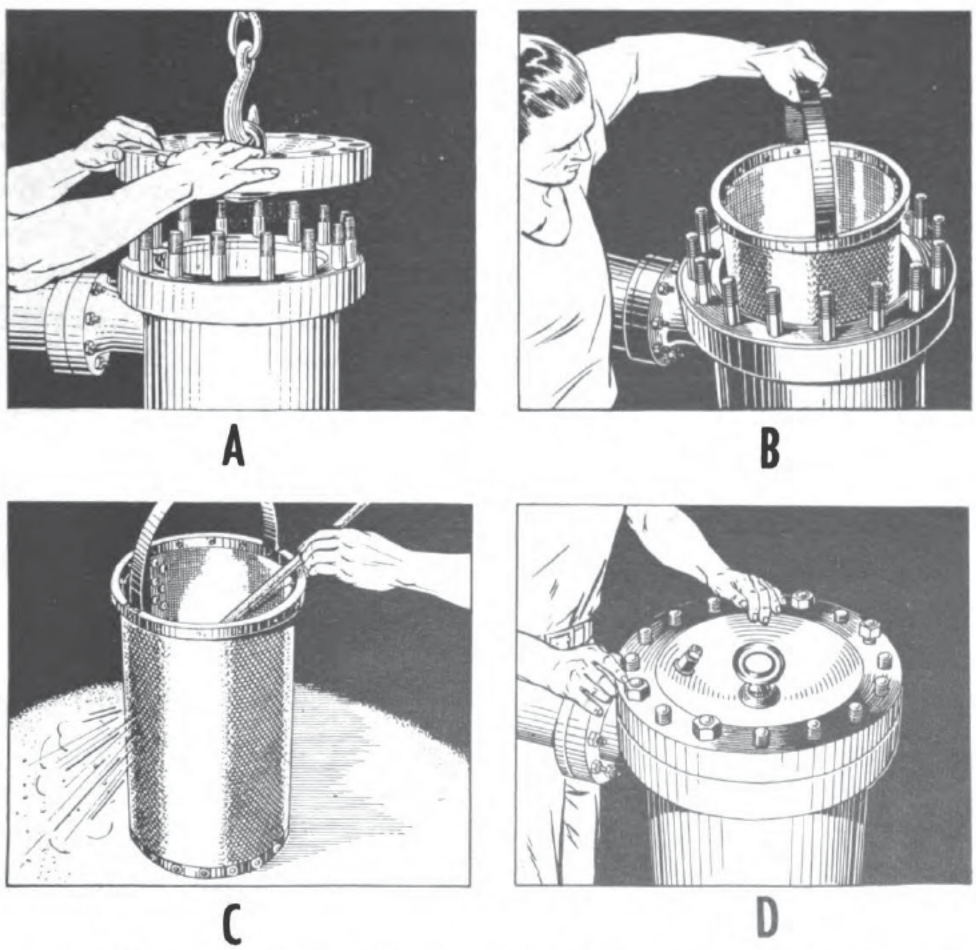


Figure 7–23.—(a) Removing strainer cover, (b) lifting strainer basket, (c) cleaning strainer basket, and (d) replacing strainer cover.

2. Open the air-cock, at the top of the strainer, and the drain valve, at the bottom of the strainer. This will drain the oil from the strainer into the sump tank.
3. Close the drain valve.
4. Loosen the bolts and remove the cover from the strainer (fig. 7–23a).
5. Lift the basket out of the strainer (fig. 7–23b).
6. Blow out all dirt and foreign matter from the strainer basket. Then clean the strainer basket thoroughly (fig. 7–23c).
7. Insert the basket into the strainer, place the cover on the strainer (using a new gasket), replace, and tighten the bolts.
8. Open the strainer intake valve and refill the strainer with oil from the system while bleeding off the air.
9. Close the air-cock and open the main-pump suction valves.

The sump-pump oil strainers should be cleaned at the same time as the main-pump oil strainers. They are cleaned by observing the following procedure:

1. Close the storage tank stop valve, the exhaust tank stop check valve, the engine stop check valve, and the sump-pump stop check valve.
2. Open the air cock and the drain valve. Then continue the procedure as outlined, under main-pump strainers, and remember to open the check valves, mentioned above, before refilling the strainer with oil.

Care and Maintenance of Main Hydraulic Pumps

Maintenance of the main pump consists mainly of draining and refilling with oil, when the oil in the hydraulic system has become dirty or mixed with water. In addition, the compensator control filter should be cleaned at least once each week.

To drain the pump, open the drain valve at the bottom of the unit. When the pump is drained, clean out dirt

and sludge, and flush the pump with acid-free cleaning fluid. Wash out all cleaning fluid and blow the pump dry with an air hose before refilling with fluid.

Use fire resistant, or safety, fluid MIL–H–19457 in the hydraulic system. (Until recently, Navy Symbol No. 2075H oil was used in hydraulic systems of aircraft elevators.) All oil must be strained through a fine (120)-mesh wire screen as it is poured into the system. The use of cloth strainers is not recommended, since the continued use of such material tends to cause an accumulation of lint in the system. This may result in the sticking of the pistons. A convenient accessory for filling may be made by soldering a piece of 120-mesh wire screen to an ordinary funnel. In some cases the usefulness of the funnel is increased by the addition of a pipe thread at the lower end. By connecting this funnel to a length of pipe, the funnel may be used for filling purposes in places that are not otherwise accessible.

See that all containers used for filling the system, or for storing oil, are clean. They must not have been used previously for acids, lyes, or other chemicals. When the pump is drained after having been in service, all dirt and sludge must be cleaned out, and the pump flushed with acid-free cleaning fluid. Before refilling with oil, all cleaning fluid must be removed from the pump, and the pump blown out with air until dry. Unless this is done, either the chemical or the physical properties of the oil may be impaired by small quantities of cleaning fluids.

In elevator hydraulic systems where petroleum oil is still used, water seeping into the pump will usually settle in low points. If the drain plugs are removed, the water will come out. If the water is found to contain a considerable amount of iron rust, the entire system must be drained and flushed, as mentioned above.

If the petroleum oil is very cloudy or murky, it has probably become emulsified with a small percentage of water. Its lubricating value is reduced, and the oil should be replaced. In an emergency, the oil can be heated to

approximately 220° F., evaporating the water; this is not recommended for general practice. Oil darkened from use but still clear should not be mistaken for emulsified oil, which is cloudy.

Hydraulic equipment which has been standing idle at extremely low temperatures should be started with care. (Before operating the equipment the entrapped air should be bled from the cylinders, control valves, strainer, and piping.) While the oil is pumpable at low temperatures, it is very viscous. A short time is required to force the oil between closely fitted parts so as to provide lubrication. Two or three minutes' operation at low pressures will provide ample time for penetration. During this time the oil will warm up and the viscosity will be greatly reduced.

A drip cup is mounted on the retainer, below the pump shaft, to catch the drip oil that might seep through the drive shaft packing. This cup should be drained occasionally, by removing the plug.

Grit and abrasive particles in the oil will cause wear which destroys the seal between the pistons and the cylinder. This results in leakage losses which reduce the efficiency beyond allowable limits. If the wear becomes excessive, the worn part should be replaced.

Cleaning and Replacing Filter Elements

Each elevator has a micronic oil filter (fig. 7–24) installed in its power system. The filter is generally designed to handle approximately 140 gpm of hydraulic oil, at a working pressure of 350 psi, with a pressure drop of approximately 5 psi. The quantity of oil passing through the unit is controlled by an orifice installed between the flanges located on the discharge side of the filter. The quantity of oil will be indicated on the Flo-Gage and the pressure drop on the Differential Pressure Gage. An internal bypass valve is installed and set to open at 20 psi above the working pressure. Stop valves are installed on the inlet and outlet sides of the filter to fa-

cilitate cleaning and/or replacement of the filter elements. The piping to the filter is arranged to take oil from the exhaust tank and discharge to the suction sides of the main pumps.

To clean all the oil in the enclosed pressure system, operate the elevator on a cycle once "up" and "down"; this takes approximately 3½ minutes. Use at least one of the main pumps to circulate the oil. Shorten the strokes of the pumps to reduce delivery so that the pumps are not automatically shut down between runs of the elevator. Close the inlet and the outlet valves of the main strainers; this will cause all the oil being pumped to pass through the filter. Watch the Flo-Gage and adjust the strokes of the pumps so that the flow does not exceed 140 gpm. Operate the elevator as frequently as necessary to keep the pumps operating, i.e., run the elevator up and down before the oil level and pressure are completely restored in the high-pressure tank which would shut off the pumps. Maintain this operation for about 30 minutes in which time all of the oil should have passed through the filter. Observe the differential pressure gage and if the indication is above five psi, stop filtering and clean the filter. After the complete cleaning of the oil, the filter can be used in parallel with the main strainer. This condition will allow about 10 percent of the oil to flow through for continuous filtering during the normal operation of the elevator.

To clean the filter, proceed as follows:

1. Place the Flo-Gage in the inoperative position.
2. Close the inlet and the outlet gate valves.
3. Slowly open the globe valve in the drain line from the bottom of the filter.
4. Open the gate valve in the drain line from the side of the filter body.
5. Close the globe valve in the bottom drain.
6. Attach the air hose (25 psi) to the one-quarter-inch size needle valve and allow air to blow back

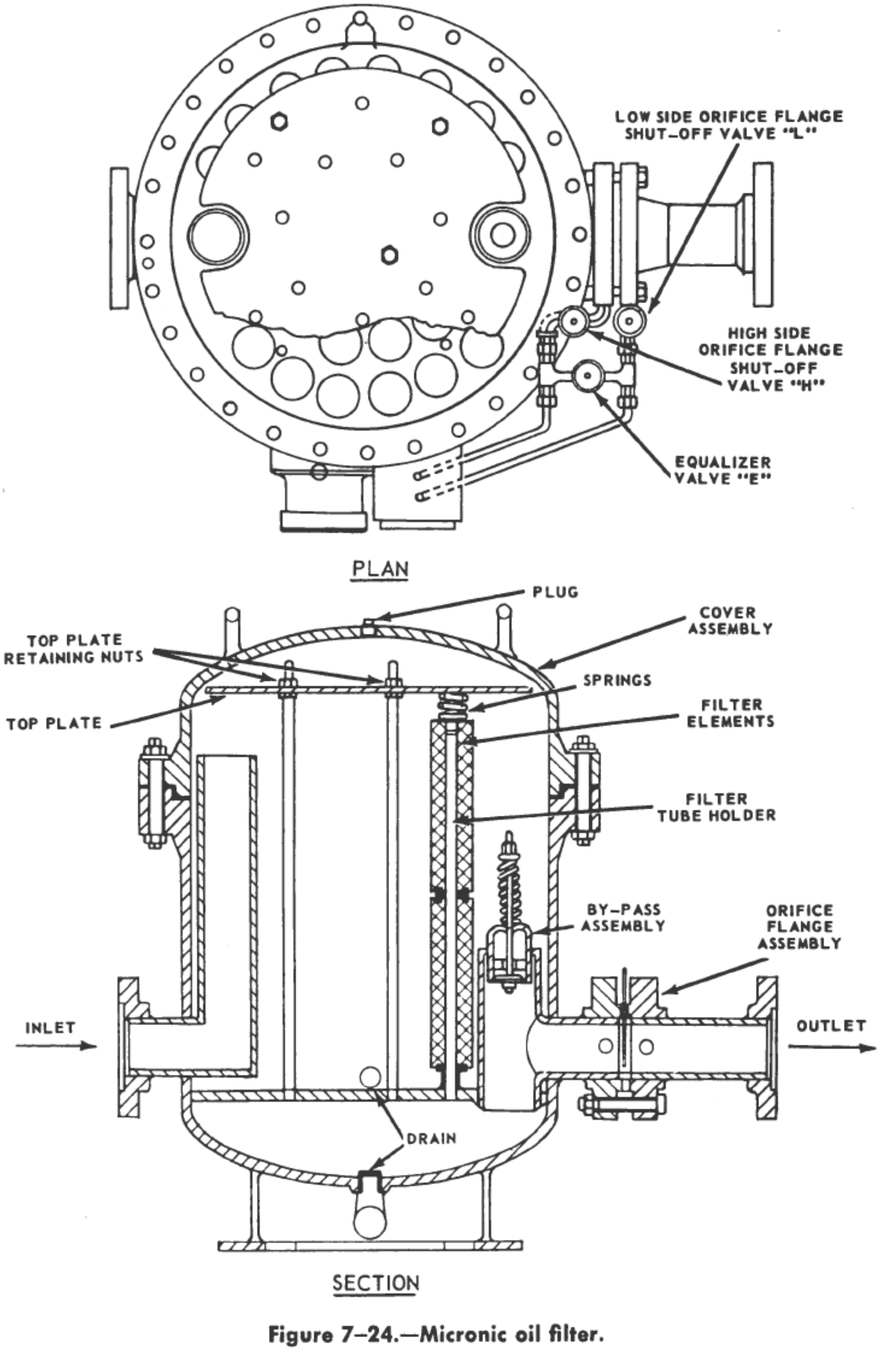
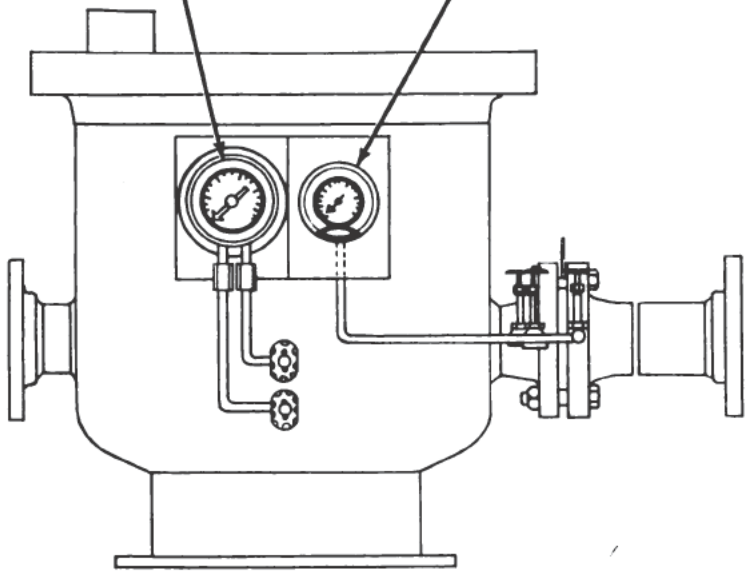
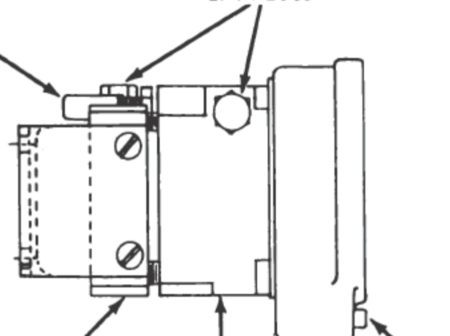


Figure 7-24.—Micronic oil filter.



ELEVATION



FLO-GAGE INDICATOR

Figure 7-24.—Micronic oil filter—Continued.

through the filter elements, through the open gate valve to the blow-down tank (fig. 7–8).

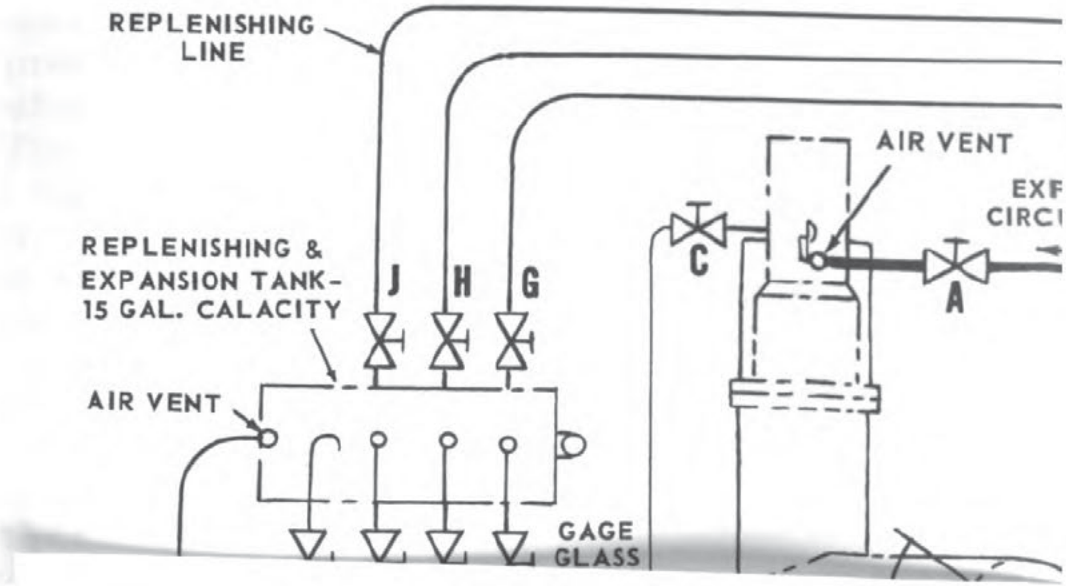
7. Close the drain and air valve, and allow the oil to settle in the blow-down tank after which a check for the cleavage point can be made by using the try cocks on the tank. Impurities in the oil can be disposed of through the one-half-inch valve installed below the blow-down tank.
8. When refilling with oil, or fluid, open the plug on top of the filter to bleed the air.
9. Open the outlet valve, and the inlet valve. Close the plug when all the air is out.
10. Place the Flo-Gage in operation.

If the filter cannot satisfactorily be cleaned, replace the filter as follows:

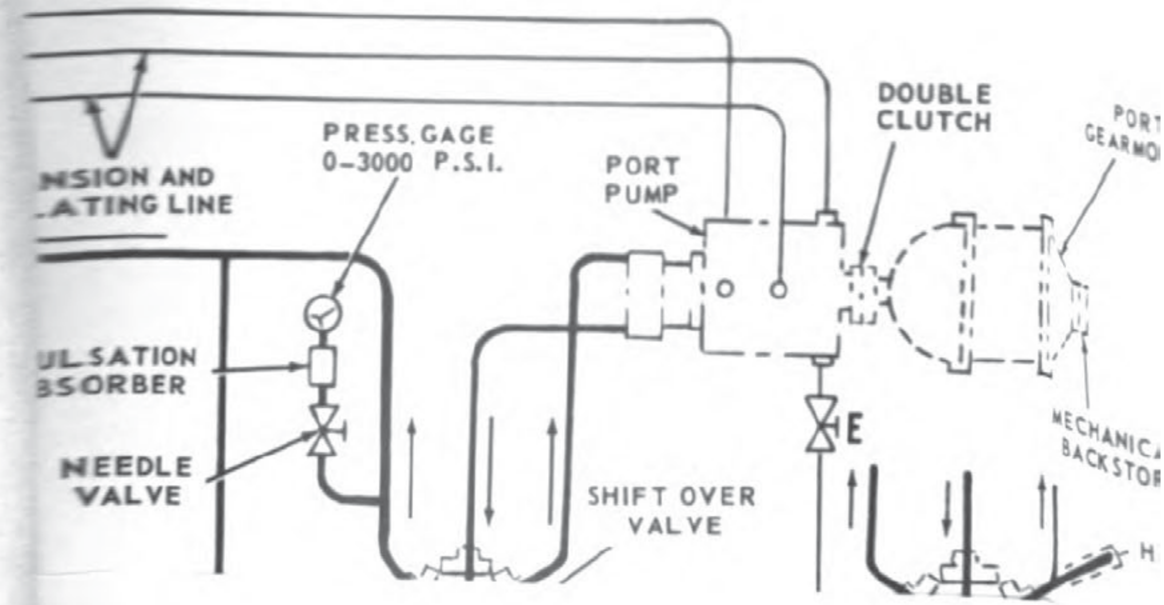
1. Proceed as for cleaning the filter elements; steps 1–4.
2. Remove the filter cover assembly, the top plate retaining nuts, the top plate, and the filter elements.
3. Before replacing the elements, wipe out any sediment on the bottom of the chamber.
4. Replace the filter elements on the filter tube holder and springs.
5. Before replacing the top plate, see that the element holders and springs are all evenly in place. Replace the top plate, the top plate retaining nuts, and the cover assembly.
6. Place the filter in operation by proceeding as in steps 8, 9, and 10 of the cleaning procedure.

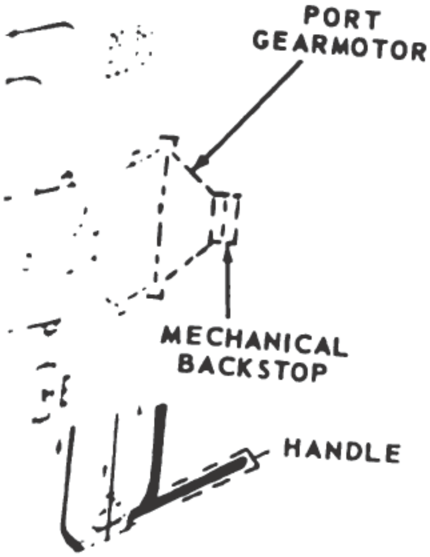
STEERING SYSTEMS

Aboard modern naval vessels, practically all steering gear installations are of the electrohydraulic type. In this type of steering gear, movement of the rudder is obtained from hydraulic rams operating in cylinders that are connected hydraulically to variable delivery pumps. The pumps are driven in one direction by continuously running electric motors. The steering gear motors, on recent



REPLENISHING
LINE
REPLENISHING &
EXPANSION TANK-
15 GAL. CALACITY
J
H
G
AIR VENT
AIR VENT
C
A
GAGE
GLASS


DOUBLE
CLUTCH
PRESS. GAGE
0-3000 P.S.I.
PORT
PUMP
NSION AND
LATING LINE
ULSATION
BSORBER
NEEDLE
VALVE
E
SHIFT OVER
VALVE
MECHANICA
BACKSTO



NOMENCLATURE FOR FIGURE 7–25

POWER STEERING

Pilot House Control

1. Disengage trick wheel clutch lever (down).
2. Check shift-over valve lever for desired power pump.
3. Check double clutch for port power pump engagement ha
4. Check hand stroker for port power pump engagement ha
5. Synchronize helm and rudder indicators placing power pu
6. Check steering gear room and pilot house selector switcl cable.
7. Depress (close) button at protective panel to energize sel

ships, are equipped with either a mechanical backstop an electric brake. These devices are automatically set to prevent the rudder from seizing control of the steering mechanism when power is lost.

The discharge volume and the direction of flow from the variable delivery pumps are controlled by the operation of the tilting box on the pump. This is accomplished mechanically by means of trick wheels in the steering gear room, and by remote control from one or more steering stations. Any movement of the control unit, to starboard or to port, places the hydraulic pump on working stroke. The pump will then supply pressure to the hydraulic rams, resulting in a corresponding movement of the rudder (starboard or port). This rudder movement actuates the followup gear which, in turn, acts to return the pump control to neutral when the rudder reaches the desired position.

There are various types of electrohydraulic steering gear layouts in use, but their operating principles are practically the same. Some ships have double hydraulic rams and cylinders mounted fore and aft; others have double-cylinder single rams mounted athwartships. Some systems use axial piston variable-stroke pumps; others use radial piston pumps. Figure 7–25 illustrates a piping diagram of an electrohydraulic steering-gear mechanism found on a typical destroyer.

Additional information concerning the principles of operation of electrohydraulic steering gears can be found in *Machinist's Mate 3,* NavPers 10522. The remainder of his section deals primarily with control devices, and ubmersible steering systems.

Control Mechanisms

Although there are a few pilot motor control systems use, the majority of naval vessels utilize either synhronous transmission or hydraulic telemotor systems. In most satisfactory control arrangements so far developed, the trick wheel and the receiver of the control sys-

tem (either synchronous receiver, hydraulic telemotor receiver, or pilot motor) are geared to, and actuate, the pump-control cam through one end of a differential to put the pump on stroke. The followup mechanism acts through the other end of the differential to reverse the movement of the cam, and to take the pump off stroke. The differential control unit and cam are so arranged that the control unit may lead the rudder by the full amount of rudder travel. If at any position of the rudder, the rudder torque becomes so great that the pressure in the ram cylinders is excessive, a safety device called a torque equalizer will automatically reduce the pump stroke in order to prevent the motor from being overloaded. (The torque equalizer usually consists of a spring-loaded piston in a hydraulic cylinder. The cylinder is automatically connected to the high-pressure side of the ram system through a shuttle valve.)

For easy steering, the manual effort required on the steering wheel must be small in magnitude. On ships which employ large variable-stroke pumps, the steering wheel (control mechanism) actuates a pilot valve which controls the flow of oil, under pressure, to and from a cylinder. The direction and amount of motion of the power piston controls the stroke of the main pump which actuates the rudder.

Adjustable control stops are provided in the control system to limit the movement of the steering wheels to the equivalent of the hardover to hardover rudder movement. To further safeguard the steering gear against damage, the rams are arranged to bring up against renewable copper stops before the rudder reaches the extreme limit of its travel. The setting of the copper stops on the tie rods, between ram slippers and steel positive stops, should be checked by experienced shipyard personnel to assure equal bearing on all stops.

In ships that are equipped with twin rudders and two independent steering gears, there is an emergency centering pump which can be used should one rudder become

inoperable. This centering pump is located in the opposite compartment from the steering gear to which it is connected. By its use, the stalled rudder can be brought to a central position where it will least interfere with the steering of the ship by the other rudder. Mechanical rudder angle indicators are provided in each compartment to show the movement of the steering gear in the opposite compartment.

Auxiliary Hand Operation

Auxiliary hand gear is provided for most ships that have electrohydraulic steering gears. This auxiliary hand gear usually consists of a hand-operated hydraulic pump supplemented by chain hoists.

The hydraulic emergency steering system consists of a relief valve, shuttle valve, hand-operated dual hydraulic pump, associated piping, valves, and fittings. The piping from the emergency pump to the main hydraulic system is arranged so that the high-pressure stop valves may be closed to prevent leakage through the main hydraulic units from the pressure developed by the hand pumps. The emergency pump is usually connected to the main hydraulic system, permitting the use of all four ram cylinders. If not connected in this manner, it is necessary to reduce the speed of the ship in order to limit the ram pressure to that permitted by the pump design. Since it is necessary to block off the emergency system under normal steering gear operation, the emergency lines are generally connected to the drain valves; this eliminates the necessity of additional high-pressure valves.

As the emergency steering system described above depends upon an intact hydraulic system for operation, rudder positioning equipment to permit steering with the propellers (after all other means of steering have been rendered inoperable) is also furnished. This equipment consists of chain hoists and suitable attachments for moving the rudder with the ship dead in the water.

Dual Emergency Submersible Steering Gear

Large and medium carriers (CV's and CVL's) and cruisers (CA's and CL's) are equipped with a dual emergency, submersible steering system. Its purpose is to provide emergency steering by either electric motor or hand power, in the event of failure of the main system. This emergency gear is usually located in the steering gear compartment of the ship. Hand operation is accomplished by use of a remotely located crank stand connected to the unit by shafting. The unit automatically connects itself to one pair of cylinders, to which it has been piped, and at the same time disconnects the main steering from these cylinders and provides a bypass circuit for the cylinders not in use. This automatic shifting is accomplished at the first few revolutions of the emergency motor-driven pump.

This submersible unit is complete within itself with a built-in shuttle valve for venting and replenishing. The shuttle valve also connects the expansion tank to the low-pressure side of the pump in either direction of rotation. When the emergency motor-driven pump is in use, the locking valve provides nonoverhauling protection as well as a means of locking the rudder in position. When the emergency hand pump is operated, these features are provided with an antikickback device. A pushbutton control station for the submersible unit is provided in a remotely located compartment.

The electric-motor controller, in a drip-proof enclosure, provides motor-starting and reversing. The overload device for a-c units is of the magnetic type and may be reset from the control stations. On d-c units, the overload device must be reset manually at the controller.

The electric motor is of submersible design and rated for continuous duty submerged. In air, the motor can be operated continuously on a cycle based on a maximum of six starts per minute at one-third-load rating.

For emergency operation, it is necessary to hold down

both the "MASTER" button and either the "RIGHT"- or the "LEFT"-rudder button. Likewise, turning of the crank-stand handles, for "left" or "right" rudder, places the emergency hand-power gear in service. A change-back from emergency to main steering requires a manual reset of the "shift-over" valve, located on the unit assembly.

Inspection and Care of Electrohydraulic Steering Gears

It is important that the exposed parts of the steering-gear rams be protected against water and damage from rolling or falling objects. The rams should be kept covered with a thin-film rust-preventive compound or a heavy oil. To protect the exposed parts from rolling objects, place a guard over the parts, and keep the steering gear compartment clear of loose gear at all times.

If rust accumulates on the rams, remove with a wire brush. Since pieces of wire might stick to the rams and be pulled into the cylinders, cover the sliding parts of the rams with clean rags during the process.

The packing followers should be tightened enough to maintain sufficient pressure on the rings to prevent leakage. A special spanner wrench is provided for turning the follower, but care should be taken not to apply excessive pressure, which may result in rapid wear and improper functioning of the packing.

The oil in a steering gear, high-pressure hydraulic system should be filtered about every 6 months. This prevents the accumulation of dirt and other foreign matter, which may injure the ram and the variable-stroke pump. When makeup oil is added to the system, the oil should be filtered through cheesecloth.

The following steps should be taken in connection with the inspection and care of electrohydraulic steering gears:

1. Check piping periodically for leaks.
2. Check oil level and condition of oil in the expansion tank.

3. Filter the oil in the high-pressure system periodically.
4. Inspect the steering gear thoroughly before putting it into operation.
5. Protect the exposed parts of the rams from water, dirt, loose objects, and the like.
6. Do not attempt to test the high-pressure relief valve; this is a job for experienced shipyard personnel only.

COMPRESSED AIR SYSTEMS

As an MM3, you used compressed air for blowing out and cleaning various units, and for operating numerous pneumatic tools. Compressed air may also have many other shipboard applications. In working with any of the compressed air systems (low-, medium-, and high-pressure), you probably found that the primary source of trouble was the compressor. Although the design and capacity of compressors vary, the maintenance procedures are essentially the same. However, remember that the care and maintenance of high-pressure compressors require additional safety precautions, and the procedures recommended by the manufacturer should be followed.

Some portions of the discussion which follows may serve as a review. Other portions of the discussion should be beneficial in your study for advancement, and helpful when you are called upon to train men.

Before proceeding with the maintenance factors of a compressed air plant, it is important to emphasize the proper use of tools. When a machine of any kind is serviced, not only the proper use but also the proper use of proper tools should be kept constantly in mind. The use of improper tools and methods can cause, and has resulted in, serious casualties to auxiliary as well as other machinery.

While modern auxiliary machinery is rugged and dependable, it is not designed to withstand abusive treat-

ment. Gasketed joints, pipe joints, and bolts are designed to safely withstand the strain required for a tight connection when the specified torque is applied with the correct tool. The application of a force in excess of that prescribed usually results in breakage. If a joint or bolt cannot be tightened without using an oversized wrench or wrench handle extension, the unit has been improperly assembled. In addition, there probably is something wrong with the flanges.

For example, in assembling newly designed high-pressure air compressors, extensive use is made of soft copper gaskets for sealing joints subject to pressures up to 3000 psi. These gaskets make a tight and dependable seal if the joint is tightened down properly. However, as the tightening pressure is applied to the joint, the copper gasket is compressed and becomes work hardened. If the joint is broken and the gasket reused, without annealing, a greater tightening force is required to make a tight seal. If a wrench extension is then used, it is possible to distort the gasketed surface or twist off the bolt without achieving a tight joint. Therefore, whenever remaking copper-gasketed joints, new copper gaskets should be used, if available. In an emergency, the used gaskets can be made fit for reuse by annealing (red heat) to the soft condition. (This is an emergency measure and should not be resorted to as a general practice.)

As an MM2, you will be required to test and renew suction and discharge valves on air compressors. In addition, you will probably have to replace packing and gaskets on air compressors. These maintenance factors are discussed in the sections which follow. Additional information dealing with the care and maintenance of air compressors can be found in *Machinist's Mate 3*, NavPers 10522 or in chapter 49 of BuShips *Manual.*

Maintaining and Replacing Air Valves

The inlet and discharge valves of compressors require special attention. When valves leak, compressor capacity

is reduced and the pressure is affected. Deviation from normal intercooler pressure may indicate a leaking or broken valve, a rise in pressure indicates a defective inlet valve, and a decrease in pressure indicates a defective discharge valve. Another sign of valve trouble is an unusually hot valve cover.

Dirt is generally the cause of leaking valves. When valves become dirty, the source of trouble can generally be traced to dirty intake air; use of an excessive amount, or of an improper grade, of cylinder oil; or excessively high air temperature, resulting from faulty cooling. Periodic inspection and cleaning of valves and valve passages minimizes the number of air valve troubles.

When air valves are removed for inspection, mark each valve to ensure that it will be replaced in the same opening from which it was removed. Inspect valves carefully and do not assemble them for cleaning unless their condition necessitates such action. Dirt or carbon can usually be removed from valve parts without disassembling the valve. If it becomes necessary to disassemble the valve, note the arrangement of the various parts so that the proper relationship will be kept when the valve is reassembled. (There are periodic shipboard reports of damage to pistons and associated valve parts resulting from improperly assembled valves which protruded in the way of the oncoming piston.) To remove carbon from valve parts, soak the individual part in a suitable solvent and then brush or scrape lightly. After drying and reassembling the valve parts, test the operation of the valve to see if it opens and closes freely. (Valve action should be tested by inserting a screwdriver through the seat ports; the valve should lift and close freely.)

Before replacing air valves in a cylinder, inspect the gaskets and replace any which are damaged. Copper-covered asbestos or plain, thin copper gaskets should be used. If these are not available, one-sixteenth-inch compressed-asbestos sheet gaskets may be used temporarily. Each valve assembly should be inserted in the same hole

from which it was removed. Since it may be difficult, in many cases, to distinguish between suction or discharge valves, extreme care must be taken when the valves are being inserted in the cylinder. Make certain that suction valves open TOWARD, and the discharge valves AWAY FROM, the center of the cylinder; otherwise serious damage or loss of capacity will result. Then place the valve cover on the cylinder, making certain that its gasket is squarely in place; draw down the opposite cover nuts evenly, and in turn, so as not to tilt the cover. Tighten down the valve setscrew or clamping bolt, drawing it tight to hold the valve on its seat. If special locknuts are not provided to seal against leakage at the threads of the valve setscrew, a turn of solder or fuse wire should be placed around the screw and set down into a recess by the locking nut.

Replacing Packing and Gaskets

Some double-acting air compressors have piston rod packing glands which may require replacement. The manufacturers' technical manuals should be referred to before replacing packing, as, especially in old designs of high-pressure compressors, metallic packing may be required. Where soft packing is satisfactory, however, use Navy symbol 1430, 1433, 1104, or 1100, or alternate rings of 1430 and 1433.

When replacing stuffing-box packing, the rings should be put in so that the joints will not be in line. The packing must not be crowded too tightly at first because it will become hard as a result of the squeezing out of the lubricant. The gland should be drawn up only slightly. After the compressor has warmed up, it should be tightened sufficiently to prevent blowing.

In replacing gaskets (head gaskets as well as frame gaskets), see that the new ones have the identical thickness as those furnished by the compressor manufacturer. This will ensure proper clearance between pistons and

heads. The following gasket materials are suitable for use on air compressors:

1. Air valve seats—thin copper, soft annealed; copper-covered asbestos; asbestos sheet ($\frac{1}{16}$ inch thick) for emergency or temporary use only.
2. Valve covers—same as above.
3. Cylinder-head joint—compressed asbestos sheet.
4. Frame joints—plant fiber sheet.

Since rubber gaskets deteriorate rapidly when subjected to oil and heat of compression, they should not be used on air compressors. When replacing gaskets, see that no air or water passages are obstructed. Gaskets used in air lines should be made of plant fiber (because of the oil, asbestos packing will not last in air lines).

QUIZ

1. What are the two general types of electrohydraulic elevators used by the Navy?
2. In case of damage to the hydraulic piping, what prevents the sudden dropping of the elevator platform?
3. What elevator component is used primarily to move aircraft between the hangar deck and the flight deck?
4. When the elevator platform is not in use, how is it held in place, at the flight deck?
5. Which platform-lock assembly prevents the locking gear from being operated until the rising platform trips the lever?
6. Under normal operating conditions, how is the operation of the elevator controlled?
7. Which unit of a closed hydraulic system draws oil from the exhaust tank, and delivers it to the high-pressure tank?
8. The angular position of the swivel yoke and the cylinder block of a main hydraulic pump is controlled by what means?
9. What is the function of the compensator of a main pump installation?
10. What is the function of the main valve of the control valve mechanism?
11. What device functions to close the main control valve when the platform arrives at a terminal?

12. In the event of failure or damage to the platform-control drive shafting, what is provided to disconnect the shafting from the control valve and to lock the platform-driven sleeve?

13. If the electrical mechanism fails to operate the elevators, which hand-control station should be used to operate the elevators?

14. When the main elevator is being lowered and the auxiliary elevator is not at its lower terminal, what prevents the elevators from colliding?

15. If it becomes necessary to replace a hydraulic engine cylinder packing, what is the first step that must be taken?

16. If a valve piston packing is leaking excessively and it becomes necessary to replace the packing, what step should be taken before removing the packing gland and the old packing?

17. When oil is strained from a main hydraulic pump, why is it not advisable to use cloth strainers?

18. What is the purpose of the torque equalizer in an electrohydraulic steering gear mechanism?

19. Why are adjustable control stops provided in the control system of a steering gear installation?

20. What is the purpose of an emergency centering pump aboard a ship equipped with twin rudders and two independent steering gears?

21. What is the purpose of a dual emergency, submersible steering system aboard large and medium carriers?

22. How often should the oil in a steering gear, high-pressure hydraulic system be filtered?

23. If the intercooler pressure of an air compressor drops below normal, what is the probable trouble?

24. Dirt which causes compressor air valves to operate improperly can usually be traced to what three sources?

25. When inserting compressor air valves in a cylinder, what precaution must be taken?

26. What can be used as a seal against leakage at the threads of an air valve setscrew, if no locknuts are provided for this purpose?

CHAPTER 8

METALS AND THEIR PROPERTIES

As a Machinist's Mate, you are well aware of the many uses of metal aboard ship. The machinery and equipment for which you are responsible is constructed, in many cases, of various types of metal. A general knowledge of metals, their properties, and the methods of identifying metals will be helpful to you in the performance of your job. You are not expected to become a Metalsmith, a Pipefitter, or a Molder. But a knowledge of the various metals will enable you to more readily understand why certain casualties may occur as a result of metal failures. You should be familiar with the terms and symbols used to identify metals so that you will not misunderstand them when you come upon such terms or symbols in technical manuals or specifications.

PROPERTIES OF METALS

The physical properties of a metal determine its behavior under stress, heat, and exposure to chemically active substances. In practical application, behavior of a material under those conditions determines its mechanical properties: its ability to resist deformation, fracture, indentation, etc. The mechanical properties of a metal, therefore, are important considerations when a metal is being selected for the construction of a machine or any of its parts. A few of the properties of metals are described in the following paragraphs.

STRENGTH.—This is the property of being able to resist strains and stresses. The maximum stress applied to rupture a material is called its ultimate strength. Under tension stress (pulling apart), ultimate strength is called TENSILE STRENGTH, and, under compression stress, it is called COMPRESSION STRENGTH. Tensile strength, usually measured in pounds of tension force necessary to cause failure of a one-inch cross section of the material, is the most commonly used strength term for metals. In engineering construction, the design of each part is such that the working stress is much less than the ultimate (breaking) strength of the material involved. The ratio of ultimate strength of a part to its working stress is called the factor of safety. A factor of safety less than 4-to-1 is uncommon; in many cases, it may be as great as 15- or 20-to-1.

DUCTILITY.—This is the property which permits a metal to be drawn out or pulled into wire form. Copper and iron are ductile materials; a rod of either may be drawn out so that as length increases there is a comparatively uniform reduction of cross-sectional area throughout the length.

MALLEABILITY.—This is the property of a metal that permits it to be hammered or rolled into thin sheets. The stresses that are applied cause a "flow" of the material; the hammering or rolling process is carried on at high or low temperatures.

BRITTLENESS.—This is the quality of breaking suddenly with little or no prior deformation. Hard materials are often brittle, although a metal may be hard and still not be brittle. An example of a brittle material is hard cast iron. On the other hand, tungsten tool steel is hard but not brittle.

TOUGHNESS.—This is the quality of having flexibility and also great resistance against deformation and tensile stress. A tough material will resist great strain and will withstand hard usage; it is not easily separated or cut, and it can be bent first in one direction and then in the

opposite direction without fracturing. Usually, toughness decreases as hardness increases.

HARDNESS.—This is that property of a metal which enables it to resist indentation, abrasion or wear, and cutting. The hardness of a metal is usually associated with its strength.

FATIGUE.—The action which takes place in a metal after a repetition of stress is known as fatigue. When a material is broken in a tensile machine, a certain definite load is required to cause the fracture; however, the same material will fail under a much smaller load which is applied and removed many times. Because of this a shaft may break after months of use, even though its loading has not been changed. In such a case, the part breaks with no sign of deformation. The final part to fracture is usually quite coarse-grained; and sections adjacent to the final fracture show signs of having rubbed together for quite some time. The coarse grain of the final fracture has often led to the erroneous conclusion that the part failed because of crystallization in service. Steel is a crystalline material but you cannot see the crystals with the naked eye the way you can see both coarse and fine grain. Metals do not crystallize or recrystallize during normal use.

CORROSION RESISTANCE.—This is the ability of a metal to withstand the gradual disintegration caused by chemical or electrochemical attack by the atmosphere, moisture, or other agents. Some metals are highly resistant to practically all types of corrosive agents, others to some types of corrosive agents, and still others to only very few types of corrosive substances. Some easily corroded metals, however, can be made less susceptible to the action of corrosive agents by coating or by alloying them with metals that are more corrosion-resistant.

HEAT RESISTANCE.—Some metals retain strength or hardness, or both, at high temperatures much better than do others. A metal that retains its strength or hardness to a high degree at high temperatures is called heat-

resistant. Tungsten steel, which can be used to cut other metals when it is red-hot, and carbon-molybdenum steel, which is used for the piping and valves of high-temperature, high-pressure steam systems, are examples of heat-resistant metals.

MACHINABILITY.—This term is used to describe the ease with which metal may be shaped with machine-shop tools. Some metals must be specially treated in order to make them machinable with the usual machine-cutting tools. Machinability determines the speed at which a metal can be cut and, in some cases, the type and shape of the cutting tool.

TYPES OF METALS

Metals are divided into two general classifications, ferrous and nonferrous. Ferrous metals are those in which the principal element is iron. Nonferrous metals are those in which the principal element is not iron; they may contain a small amount of iron as an impurity or alloy.

Ferrous Metals

The main source of all ferrous metals is iron ores, the most common of which is red hematite. The conversion of the ore to metal takes place in the blast furnace, where the iron ore, mixed with coke and limestone, is melted.

IRONS.—The product of the blast furnace is called PIG IRON. In early smelting practice, the arrangement of the sand molds into which the molten crude iron was drawn resembled groups of nursing pigs; hence, the name pig iron.

Pig iron, which contains approximately 93 percent iron, 3 to 5 percent carbon, and varying amounts of impurities, is seldom used directly as an industrial manufacturing material. It is, however, the basic ingredient of cast iron, wrought iron and steel.

Remelting a charge of pig iron and scrap iron in a furnace and removing some of the impurities from the

molten metal by various fluxing agents produces CAST IRON. There are many grades of cast iron; grades are based on strength and hardness. The quality of cast iron depends upon the extent of refining, the amount of scrap iron used, and the method of casting and cooling the molten metal when it is drawn from the furnace. The higher the proportion of scrap iron used, the lower will be the grade of the cast iron produced. Cast iron has some degree of corrosion resistance and great compression strength, but the metal is brittle and has a comparatively low tensile strength.

When pig iron is refined through a process known as puddling, the product is called WROUGHT IRON. Wrought iron is considerably softer than cast iron and has a fibrous internal structure, created by the rolling and squeezing it receives when it is being made; but, like cast iron, it is fairly corrosion-resistant. Wrought iron, because of these characteristics, is used in the manufacture of low-pressure pipe, rivets, and nails.

CARBON STEEL.—Pig iron is converted into steel by complex smelting and refining processes which separate and remove impurities from the molten iron by the use of various catalytic agents and extremely high temperatures. During these processes, practically all of the carbon which was originally present in the pig iron is burned out. However, in the final stages of these processes, measured amounts of carbon are added to the relatively pure liquid iron to produce carbon steel of a desired grade. The amount of carbon so added determines the mechanical properties of the finished steel to a large extent, as will be pointed out in succeeding paragraphs.

As soon as the steel has been drawn from the furnace and allowed to solidify, it may be sent either to the stockpile or to the shaping mills for rolling and forming into plates, billets, bars, or structural shapes.

Low carbon (0.05 to 0.030 percent) steel, usually referred to as MILD STEEL, can be easily cut and bent. It

does not have great tensile strength, as compared to other steels.

Steel with 0.30 to 0.60 percent carbon is called MEDIUM STEEL. It is considerably stronger than mild steel. Main bulkheads, frames, decks, and shell plating of ships are all made of medium steel.

Metal with 0.60 to 1.25 percent carbon is called HIGH CARBON STEEL. The common term for steels with a carbon content in the range indicated is CARBON TOOL STEEL. Steels of this type are used in many machine parts, hand tools, and cutting tools.

ALLOY STEELS.—The steels discussed thus far are true alloys of carbon and steel. When other elements are added to the iron during the refining and smelting processes to produce a tougher, stronger, harder, or more corrosion-resistant metal than is possible with the addition of carbon alone, the resulting metal is called an alloy steel. There are many types, classes, and grades of alloy steel. A few of the more common alloy steels and the effects of certain alloying elements upon the mechanical properties of steel are discussed briefly in the following paragraphs.

A steel which is tougher and harder than plain carbon steel is referred to as HIGH TENSILE STEEL (HTS). Small amounts of various alloying elements give such a steel its extra toughness and hardness. As an example, one HTS steel contains the following amounts of alloying elements: 0.20 percent manganese, 0.10 percent silicon, 0.35 percent copper, 0.50 percent nickel, 0.05 percent molybdenum, 0.05 to 0.15 percent phosphorous, and 0.12 percent carbon.

The metal which gives the greatest protection to the vital parts of a fighting ship must provide great resistance to penetrating and shearing forces. These requirements are met by a specially treated steel which is particularly tough and hard. This type of metal is called SPECIAL TREATED STEEL (STS); the alloying elements are chromium and nickel, present in small amounts.

Gun shields, turrets, barbettes, conning towers, and protective decks are made of STS; protective belts surrounding the vital areas of a ship, such as the machinery spaces and the magazines, are also made of STS.

A steel which is corrosion resistant but which is not as tough as HTS or STS is STAINLESS or CORROSION RESISTING STEEL. In appearance, stainless steel is bright and shiny. The grade of a stainless steel is governed by its content of chromium and nickel; the percentages of these alloying elements are indicated by numbers. For example, 18–8 stainless steel contains 18 percent chromium and 8 percent nickel. The stainless steels most commonly used are 18–8 and 25–20. Because of its high resistance to corrosion, stainless steel is much used around hatches, and in galleys and sick bays. It is often used for its decorative effect and on shipboard instruments that are exposed to the weather.

Steels which contain 3 to 5 percent nickel are called NICKEL STEELS. They have superior strength and toughness, and are highly resistant to corrosion.

Crankshafts, gears, and other machine parts in which extreme hardness is desired are constructed of VANADIUM STEELS. Steels of this type usually contain 0.15 to 0.25 percent vanadium, 0.60 to 1.50 percent chromium, and 0.10 to 0.60 percent carbon.

Molybdenum, along with chromium and nickel, is added to steel to produce a tough CARBON-MOLYBDENUM STEEL, which is suitable for large crankshafts, propeller shafts, and boiler plates. Molybdenum is also used, in place of the more expensive tungsten, for the cheaper grades of high-speed steel cutting tools.

TUNGSTEN STEEL has the quality of red-hardness; because of this, cutting tools made of tungsten steel can be used up to, and after, the time when the point becomes red-hot. Tungsten cutters are good for cutting cast iron and some nonferrous metals; but it takes three times as long to sharpen a tungsten cutter as it does to sharpen a high-speed steel cutter. Tungsten-chromium-vanadium

steel (14-4-2) is particularly tough, but expensive to produce.

Nonferrous Metals And Alloys

The more common nonferrous metals which are either in the form of the pure metal or as the principal element in alloys are copper, zinc, lead, tin, aluminum, nickel, cadmium, magnesium, tungsten, silicon, and molybdenum. Some of the more important nonferrous elements which are used primarily as alloying elements are antimony, vanadium, chromium, and manganese. A few of the nonferrous metals are described here.

COPPER.—This is a metal which lends itself to a variety of uses. You will see it aboard ship in the form of wire, sheet, plate, and pipe; and in copper alloys such as brass and bronze. As a conductor of both heat and electricity, it ranks next to silver; it also offers a high resistance to salt-water corrosion. The green tarnish which sometimes forms on its surface has little detrimental effect upon the metal, and is easily cleaned off.

Copper becomes hard when worked, but you can easily soften it by heating it to a cherry-red color and then allowing it to cool. Its strength, however, decreases rapidly with increases in temperatures above 400° F.

ZINC.—This is a comparatively soft, yet somewhat brittle metal. Its tensile strength is only slightly greater than that of aluminum. In the manufacture of brass, zinc is used as alloying metal, copper being the base metal. Because of its resistance to corrosion by the atmosphere and by water, zinc is used as a protective coating for less corrosion-resistant metals, principally iron and steel. There are three methods of applying the zinc coating: (1) Electroplating in a zinc-acid solution; (2) hot dipping, where the metal to be coated is dipped into a bath of molten zinc; (3) sherardizing, where zinc is reduced to a gaseous state and deposited on the base metal.

Pure zinc, being strongly electropositive, is used to protect water-cooled heat exchangers and the hulls of steel ships against the electrolysis established when salt water connects two dissimilar metals in a closed circuit. Zinc plates bolted to the hull, especially those near the propellers, decompose quite rapidly; in doing so, however, they greatly reduce localized pitting of the hull steel.

LEAD.—This is one of the heaviest of metals; a cubic foot weighs approximately 700 pounds. Lead is grayish in color; and it is soft and pliable. It is obtainable in sheets and pigs. The sheets will normally be wound around a rod of some sort and pieces can be cut off quite easily. One of the most common uses of lead is its use as the alloying element in soft solder.

TIN.—This metal is seldom used except as an alloying ingredient. Alloyed with lead it makes a soft solder, and alloyed with copper, it produces bronze. Lead and tin both resist corrosion very well, but tin has the added advantage of being nonpoisonous. It is for this latter reason that many food containers are fabricated from sheet material which has been coated with tin.

ALUMINUM.—This metal is being used more and more in ship construction because of its light weight, easy workability, good appearance, and other desirable properties. Pure aluminum is soft and not very strong; when alloying elements such as magnesium, copper, nickel, and silicon are added, however, a much stronger metal is produced.

Pure aluminum is highly resistant to corrosion, but aluminum alloys soon corrode unless properly protected. The content of the alloying agents determines, to some extent, the rate of corrosion. Zinc chromate is one of the best protective coatings for aluminum surfaces. Another type of protective coating, referred to as "alclad," consists of a thin sheet of pure aluminum rolled onto the surface of an aluminum alloy at the time of manufacture.

NICKEL.—A hard, malleable, and ductile metal, nickel

is resistant to corrosion and is therefore often used as a coating on other metals. Combined with other metals in an alloy, its effect is to make the alloy tough and strong.

BRASS.—True brass is an alloy of copper and zinc. Complex brasses are those which contain additional alloying agents, such as aluminum, lead, iron, manganese, or phosphorus. Rolled naval brass is a true brass containing about 60 percent copper and 40 percent zinc; it is corrosion resistant.

BRONZE.—The best metal available before steel-making techniques were discovered was a bronze made of 84 percent copper and 16 percent tin. Many complex bronze alloys containing three or more elements have been developed. There is little difference between brass and bronze. In fact, commercial bronze contains 90 to 95 percent copper and 5 to 10 percent zinc.

COPPER-NICKEL ALLOY.—This alloy has the general working characteristics of copper, but it must be worked cold. Copper-nickel alloy may contain 70 percent copper and 30 percent nickel or 90 percent copper and 10 percent nickel. It is used extensively aboard ship because of its high resistance to the corrosive effect of salt water. It is used in piping and tubing; in sheet form, it is used in the construction of small storage tanks and hot-water reservoirs.

NICKEL-COPPER ALLOYS.—These metals are stronger and harder than either nickel or copper. They have high resistance to corrosion, good ductility, and are strong enough to be substituted for steel where resistance to corrosion is of primary importance.

Probably the best known nickel-copper alloy is Monel metal. (Monel is a trade-mark for a product of the International Nickel Company.) Monel, which contains 64 to 68 percent nickel, about 30 percent copper, and small percentages of iron, manganese, silicon, and cobalt, was formerly a natural alloy since the indicated combination of nickel and copper existed in the ore when it was mined.

Standard alloying methods are generally used now. The excellent qualities of Monel make it valuable for use in pump parts, turbine blades, table tops, laundry equipment, steam valves, containers, and head fixtures and equipment. Nuts, bolts, screws, control parts, and other fittings are also made of Monel.

An improved type of nickel-copper alloy, stronger and harder than ordinary Monel, is called K-monel. K-monel is essentially the same as Monel except that it contains about 3 percent aluminum. The strength of K-monel is comparable to that of heat-treated steels.

ANTIFRICTION ALLOYS (BEARING METALS).—Bearings of the sliding-surface type are made of nonferrous metals. A bearing metal must have a low coefficient of friction with the moving part which the bearing supports or guides. The metal used for bearings must also be capable of conducting the heat of friction away from the point of sliding contact. The alloys developed with structures which meet the requirements of bearing metals may be grouped into two classifications: hard and soft. Antifriction (bearing) alloys may also be classified according to the base metal of the alloy: copper, tin, lead, zinc, and aluminum. Copper-base alloys (hard) and tin-base alloys (soft) are the most widely used for sliding-surface bearings.

Copper-base bearing alloys are relatively hard metals; they are composed primarily of copper but contain some lead and tin and a very small amount of zinc. A copper-base bearing metal is used where strength and resistance to salt-water corrosion are required. Main, stern tube, strut, and spring bearings are often made of copper-base alloys. Bearings made of these alloys must be machined and carefully fitted. Hard bearing metals have a lower coefficient of friction than soft bearing metals.

Tin-base bearing alloys are relatively soft metals. They contain, in addition to the base metal, copper, antimony, and a small amount of lead. Such a soft bearing metal is frequently referred to as babbitt metal. Babbitt is com-

monly used as the lining in compound bearings, in which the soft bearing metal is supported in a shell of harder metal. Whereas bearings of hard metal tend to seize the shaft journal when overheating occurs, babbitt metal resists sticking to the shaft journal. In addition to its antiseizure quality, babbitt metal is highly resistant to corrosion; its fatigue strength, however, is relatively poor. Bearings made of soft metals are more easily fitted than bearings of hard metals. Babbitt metal also conducts heat away from the bearing surfaces more readily than hard bearing metals. A small quantity of hard foreign particles may be safely trapped and embedded in soft metal bearings without damage to the sliding surfaces. Bearings of tin-base alloys are used in practically all types of applications where high speeds and light or medium loads are encountered.

HEAT TREATMENT OF METALS

Heat treatment is the operation (or combination of operations), involving heating and cooling of a metal in its solid state, which is designed to develop in the metal a particular desirable mechanical property, such as hardness, toughness, machinability, or uniformity of strength. Heat treatment is based upon the effect that the rate of heating, the temperature to which the metal is heated, and the rate of cooling have on the molecular structure of a metal.

There are several forms of heat treating. The forms most commonly used for ferrous metals are: annealing, normalizing, hardening, tempering, and case-hardening.

Annealing

The chief purposes of annealing are: (1) to relieve internal strains; and (2) to make a metal soft enough for machining. The process is accomplished by heating the metal to above the critical temperature, holding it at this temperature until all of the structure is homogeneous, and then allowing it to cool slowly. Both the tempera-

ture of the operation and the rate of cooling depend upon the metal being treated, and the purpose for which it is to be used.

Besides rendering metal more workable, annealing can also be used to alter other physical properties of metal, such as magnetism and electrical conductivity. Annealing is often used for softening NONFERROUS ALLOYS and pure metals after they have been hardened by cold work. Some of these alloys require annealing operations which are different from those for steel. For example, duralumin is heated to 986° F. and is then cooled very rapidly by water-quenching. It is then workable for about 45 minutes, after which time it becomes hard again.

For FERROUS METALS, the annealing method most commonly used (if a controlled-atmosphere furnace is not available) is to place the metal in a cast-iron box, and to pack sand or fire clay around the metal to prevent oxidation. The box is placed in the furnace, heated to the proper temperature, held at that temperature for a sufficient period, and then allowed to cool slowly in the sealed furnace. This is called the annealing cycle (time vs. temperature). The annealing temperatures are usually in the range of 1,450° to 1,750° F.

In brief, the manner by which the more common metals are annealed is as follows:

1. STEEL. Heat slowly to between 1,450° and 1,750° F. (depending on its use). Hold at specified temperature for one hour for each inch of cross-sectional area, and then allow to cool slowly in the furnace or annealing box.
2. CAST IRON. Heat slowly to between 900° and 1,050° F., depending on composition. Hold at the specific temperature for 30 minutes, and then allow the metal to cool slowly in the furnace or annealing box.
3. STAINLESS STEEL (8.5–22). Heat to between 1,650° and 1,750° F. Do not soak; that is, leave the metal in the furnace only long enough to

be heated to the prescribed temperature. Cool slowly to room temperature.

4. STAINLESS STEEL (18–8). For full annealing, heat to between 2,000° and 2,200° F. and cool rapidly. For partial annealing, heat to between 1,600° and 1,700° F. and cool rapidly.
5. STAINLESS STEEL (25–20). Heat to between 2,000° and 2,100° F. Do not soak. Cool in still air.
6. COPPER. Heat to 925° F. Quench in water. (A temperature as low as 500° F. will relieve most of the stresses.)
7. ZINC. Heat to 400° F. Cool in open, still air.
8. ALUMINUM. Heat to 750° F. Cool in open air. (This reduces hardness and strength but increases electrical conductivity.)
9. NICKEL-COPPER ALLOYS, INCLUDING MONEL. Heat to between 1,400° and 1,450° F. Cool by quenching in water or oil.
10. NICKEL-MOLYBDENUM-IRON and NICKEL-MOLYBDENUM-CHROMIUM ALLOYS (known commercially as Stellite). Heat to between 2,100° and 2,150° F. Hold at this temperature for a suitable time, depending on thickness. Follow by rapid cooling in a quenching medium.
11. BRASS. Annealing to relieve stress may be accomplished at a temperature as low as 600° F. Fuller anneals may be accomplished with higher temperatures. Larger grain size and loss of strength will result from temperatures which are too high. Do not anneal at temperatures exceeding 1,300° F. Brass should be cooled slowly to room temperature. (The cooling process may be slowed by either wrapping the part with asbestos cloth, or burying it in slaked lime or other heat-retarding material.)
12. BRONZE. Heat to between 800° and 1,450° F.

Cool in open furnace to 500° F., or place in a pan to avoid uneven cooling caused by draft.

Normalizing

Normalizing is a process very similar to annealing, but it is done for a different purpose. Normalizing relieves stresses and strains caused by welding, forging work, uneven cooling of castings, etc. The metal is heated from 50° to 100° F. above its critical temperature (see Hardening, below), and is then allowed to cool uniformly in air.

Hardening

Cutting tools, chisels, twist drills, and many other tools and pieces of equipment must be hardened to enable them to retain their cutting edges. Surfaces of roller bearings, parallel blocks, and armor plate must be hardened to prevent wear or penetration. Metals and alloys can be hardened in several ways; a brief general description of one method of hardening is given below.

Each steel has a critical temperature at which there will occur a marked change in the grain structure and other physical properties. This critical temperature varies according to the carbon content of the steel. To be hardened, steel must be heated to a point slightly above this critical temperature—to ensure that every point in it will have reached critical temperature, and to allow for some slight loss of heat when the metal is transferred from the furnace to the cooling medium. It is then cooled rapidly by being quenched in oil, fresh water, or brine. Quenching firmly fixes the structural changes which occurred under heating, and thus causes the metal to remain hard.

If the metal is allowed to cool too slowly, it will lose its hardness. On the other hand, to prevent too rapid quenching—which would result in warping and cracking—it is necessary to use oil instead of fresh water or salt water for quenching high-carbon and alloy steels.

Salt water, as opposed to fresh water, produces lower hardness.

Tempering

This process is employed as a method of relieving the strains that are brought about in steel during the hardening process. Tempering makes the metal tougher and less brittle. Tempering is accomplished by heating the hardened steel to a temperature below the critical range, holding this temperature until the whole piece has attained the same temperature, and then cooling the piece slowly in air. In this process, ductility and toughness are improved but tensile strength and hardness are reduced.

Case-Hardening

This is a process of heat treating by which a hard skin is formed on a metal, while the inner part remains relatively soft and tough. A metal that is low in carbon content is packed in a substance high in carbon content, and is then heated above the critical range of the metal. (The case-hardening furnace must give a uniform heat.) The length of time the piece is left in the oven at this high temperature determines the depth to which carbon is absorbed. A commonly used method of case-hardening is to (1) carburize the material, (2) allow it to cool slowly, (3) reheat the material, and (4) harden it by quenching in water. Small pieces such as bolts, nuts, and screws, however, can be dumped into water as soon as they are taken out of the carburizing furnace.

TESTS USED TO DETERMINE THE PROPERTIES OF METALS

A number of tests are used to measure the physical properties of metals and to determine whether a metal meets specification requirements. Some of the more common tests are hardness tests, tensile strength test, shear strength tests, bend tests, fatigue test, and compression tests.

Hardness Tests

Most metals possess some degree of hardness—that is, the ability to resist penetration by another material. Many tests for hardness are used, the simplest of which is the file hardness test.

FILE HARDNESS TEST.—This is the oldest and most useful of the testing methods. To determine whether or not a metal is hard, rub the surface of the metal slowly but firmly with the sharp teeth of a file. As soon as you discover whether the file will bite, remove it. The simplicity of this method makes it especially valuable for consecutive tests, such as testing the hardness of teeth on a gear. This test is probably better for testing wearing metals such as gears than for testing cutting tools, since the cutting or abrasion made by the file closely resembles effect of normal wear on moving machine parts. It has been found that often a chisel or other cutting tool will give good service although it is soft enough to be cut with a file.

Three factors that influence comparisons of file hardness tests are:

1. The size, shape, and sharpness of the file.
2. The speed, pressure, and angle of the file while the test is being made.
3. The composition of the metal being tested and the heat-treatment it has received.

The use of a special file made for testing will eliminate, in part, the error that is inherent in file testing. For beginners, a master test block may be used to advantage. In using such a block, try the file on a block of the desired hardness; then, by comparison, you can ascertain whether the metal to be tested is softer, harder, or just the same as the hardness of the master test block. At any rate, the file chosen should be uniform and standard. A 10-inch single-cut mill file is a good file to use.

The speed, pressure, and angle of the file while the test is being made are controlled by the skill of the workman. The slower the speed, the more accurate the test. If your tests are to be of any value, they must be made at the same speed and pressure. High speeds will wear off the surface of both the file and the part being tested, thus giving the false impression that the metal being tested is soft. Light pressure and high speed will wear away the surface of the metal being tested faster than heavy pressure and low speed. A narrow surface will cut faster than a broad surface. It is best to clamp the part to be tested in a vise so you can test with the file at the same angle at all times.

In short, we may say that if the material is cut by the file with extreme ease and tends to clog the spaces between the file teeth, it is VERY SOFT. If the material offers some resistance to the cutting action of the file and tends to clog the file teeth, it is SOFT. If the material offers considerable resistance to the file but can be filed by repeated effort, it is HARD and may or may not have been heat-treated. If the material can be removed with extreme effort and in small quantities, it is VERY HARD and has probably been heat-treated. If the file slides over the material and the file teeth are dulled, the material is EXTREMELY HARD and has been heat-treated.

File testing is an art acquired by experience. It is not a scientific method. The greatest objection to the use of the file test is that no accurate records can be kept. But it can be used very successfully, especially when no other available instrument is suitable; for example, for testing the hardness of oddly shaped pieces. One who uses a file for testing soon learns to allow for the factors that might influence the test, and finds the file test an extremely useful means of measuring hardness. The required skill is not difficult to acquire.

MACHINE TESTS.—There are a number of machine hardness tests. Two of the more common tests are those

made with the Rockwell and the Brinell testing machines. You will find reference to the Rockwell and Brinell hardness numbers as you study about engineering materials.

Of all hardness tests, the Rockwell is the one most frequently mentioned. It operates on the principle of measuring the indentation in a test piece of metal made by a ball or cone of a specified size which is being forced against the test piece of metal with a specified pressure. A 120° diamond cone is used to make impressions in the harder metals and a one-sixteenth-inch steel ball is used for the softer metals. A dead weight, acting through a series of levers, is used to press the cone or ball into the surface of the metal to be tested. Then the depth of penetration is measured. The softer the metal, the deeper the impression will be under a given load. The average depth of penetration on samples of very soft steel is only about 0.008 of an inch. The hardness is indicated on a dial which is calibrated in the Rockwell B and the Rockwell C hardness scales. The harder the metal, the higher the Rockwell number will be. For testing hard steels, the diamond point should be used and the reading should be taken from the C scale. For nonferrous metals, the B ball is used and the reading is taken from the B scale.

The Brinell hardness testing machine provides a convenient and reliable hardness test. The machine is not suitable, however, for thin or small pieces. The Brinell hardness number is found by measuring the distance a steel ball is forced, under a specified pressure, into the test piece. The greater the distance, the softer the metal; and the lower the Brinell number will be. The width of the indentation is measured with a microscope and the hardness number corresponding to this width is found by consulting a standard chart. This machine is of greatest value in testing soft and medium-hard metals and in testing large pieces. On hard steel the imprint of the ball is so small that it is difficult to read.

Tensile Tests

Tensile strength may be defined as resistance to longitudinal stress or pull, and is usually expressed as stress in pounds per square inch of cross-sectional area. Tensile tests are made to determine the tensile strength of metal. Tensile tests are also used to test the strength of welds.

The usual procedure for determining tensile strength is to insert the specimen between the jaws of a tensile-test machine and increase the load (tension) gradually until the specimen fails. (The width and the thickness of the specimen must have been measured before the testing.) The machine indicates the load, or pull, in pounds when the failure occurred. To find the tensile strength of the specimen:

$$\frac{\text{TENSILE LOAD, IN POUNDS}}{\text{CROSS-SECTIONAL AREA OF TEST SAMPLE, IN SQUARE INCHES}} = \text{TENSILE STRENGTH, EXPRESSED IN POUNDS PER SQUARE INCH.}$$

In addition to portable-type testing machines, the Navy uses stationary-type tensile testing machines at some shore stations. A portable machine operates on the hydraulic principle and is capable of bending as well as pulling a specimen. As a specimen is tested, the load in pounds is registered on a gage located on one side of the portable-type machine. In the stationary-type machine, the load applied to the test specimen is registered on a balancing beam or gage. In either case, the load at the point of breaking is recorded.

Bend Tests

The ductility of a metal may be checked roughly by bend tests. Bend tests are used principally to check welds. Three tests which may be made are: Free bend, back bend, and guided bend. The procedures to be followed when the bend tests are being performed are described in *Metalsmith 3 & 2,* NavPers 10565–B.

Other Tests

The hardness, tensile, and bend tests are only a few of the tests to which metals may be subjected. Among other tests used to determine the properties of metals are the compression test, shear test, and fatigue test.

The compressive strength and the elasticity of metals are determined with the COMPRESSION TEST. Compressive strength is that property of a metal which resists forces which tend to squeeze (compress) the metal together. The test is the reverse of the tensile strength test. Compression tests are used for testing bearing metals.

Rivets are subjected to shear. A measure of the resistance (shear strength) that a metal has to shear is determined by the SHEAR TEST. Shear strength of a metal is figured from the amount of pressure required to force a disk from the metal with the use of a punch and die.

A metal which will withstand a steady load for an indefinite length of time may fail when the load is applied and removed a great number of times. Such a failure is called fatigue failure. The resistance a metal has to fatigue failure is determined by the FATIGUE TEST. The test measures the amount of bending back and forth (repetitions of stress) that is necessary to bring a piece of metal to the breaking point without any actual breaking taking place.

Another group of tests (known as nondestructive tests) are used primarily for inspection purposes. The X-ray test, the magnetic particle inspection, the fluorescent penetrant inspection and the ultrasonic inspection are included in this group of tests. These tests are used in the inspection of finished products to determine their suitability for service, and to determine whether or not the product meets the requirements of the specifications. These tests are also used by metalsmiths in the inspection of the quality of critical welds.

METHODS OF IDENTIFYING METALS

When written material on metals is being prepared, some means of distinguishing one metal from another must be used. When work is being accomplished with metals or when metal is being selected for a job, it may be necessary for a specific metal to be identified. Because of the great number of different kinds and grades of metals, several methods of identification have come into use. Various symbols, codes, and tests are used to identify metals. In order that you may be familiar with the manner in which metals are identified, a few of the methods of identification are described in this section.

SYMBOLS AND OTHER INFORMATION ON MATERIALS
(Values are approximate)

Material	Symbol	Specific gravity	Weight (pounds per cu. in.)	Melting point (°F)
Aluminum	Al	2.70	0.10	1,214
Antimony	Sb	6.62	.23	1,166
Beryllium	Be	1.85	.07	2,345
Cadmium	Cd	8.65	.31	609
Carbon	C	2.22	.08	6,332
Chromium	Cr	7.14	.26	2,822
Cobalt	Co	8.90	.32	2,714
Copper	Cu	8.94	.32	1,981
Iron	Fe	7.87	.28	2,795
Lead	Pb	11.34	.41	621
Magnesium	Mg	1.74	.06	1,204
Manganese	Mn	7.44	.63	2,268
Molybdenum	Mo	10.20	.37	4,748
Nickel	Ni	8.90	.32	2,646
Phosphorus	P	1.82	.07	111
Platinum	Pt	21.46	.78	3,224
Silicon	Si	2.40	.08	2,600
Silver	Ag	10.49	.38	1,760
Sulfur	S	2.07	.08	235
Tin	Sn	7.30	.26	449
Titanium	Ti	4.50	.16	3,272
Tungsten	W	19.30	.70	6,098
Vanadium	V	5.68	.21	3,110
Zinc	Zn	7.14	.26	787

Symbol Letters for Materials

The table on page 297 includes the symbols for the more commonly used metals. In addition to the symbols the table also includes the specific gravity, weight in pounds per cubic inch, and melting point of each material listed. The values shown are approximate; they can be used, therefore, only for the purpose of comparison.

A knowledge of the symbols shown in the table will be useful because engineering literature dealing with materials frequently uses symbols instead of names for the identification of metals. In addition, symbols are used in material specifications.

Many of the symbol letters used to identify metals are taken from the Latin counterparts of the English names of metals. For example, the symbol Fe is the first two letters of the Latin word "ferrum," which means iron. Another example is copper, the symbol for which, Cu, is taken from the Latin word "cuprum."

Symbol Numbers for Steels

The great number of different kinds and grades of steels used in the manufacture of automobiles prompted the Society of Automotive Engineers (S.A.E.) to devise a symbol identification and specification system for their use. This system has been adopted throughout the manufacturing world.

S.A.E. uses a four-digit identification system for steels. For the simpler alloys, the first digit indicates the alloy type; the second digit, the approximate percentage of the predominant alloying element; and the last two digits, the carbon content (in hundredths of 1 percent). The alloy types represented by the first digit numbers are as follows:

1—plain carbon steel
2—nickel
3—nickel-chromium

4—molybdenum
5—chromium
6—chromium-vanadium
7—tungsten
8—(was used during World War II to indicate National emergency steel)
9—silicon-manganese

To show how the system works, here are a couple of examples. S. A. E. 1008: the first digit indicates plain carbon steel; the second number is zero, since there actually is no other alloying agent; the last two digits, 08, indicate a carbon content of 0.08 percent. S. A. E. 2340: the first digit indicates nickel as the predominant alloying element; the second digit then indicates a 3 percent nickel content; and the last two digits indicate 0.40 percent carbon.

Navy blueprints ordinarily specify materials by Federal or Military specification numbers. The Navy supply system also uses these specifications to classify metals. However, from time to time, you may find it necessary to interpret an S. A. E. steel symbol number in terms of one of the specification systems mentioned above. One method of doing this is to check through Class 95 of the *Catalog of Navy Material,* General Stores Section. In many cases you will find that the S. A. E. number is given along with the description of the particular stock item. For example, carbon steel under Military specification MIL–S–866, class 1016, is described as corresponding to S. A. E. steel 1015.

Color Markings for Metals

There are a number of methods by which metals may be identified. One such method involves the use of color markings which are painted on stock. The system for the identification of metals by color marking is described in the *U. S. Navy Metal Color Marking Guide,* 1 July 1956. If your duties require a knowledge of the color

marking system, it will be advisable to obtain a copy of the most recent edition of the color marking guide.

The 1956 edition of the metal color marking guide provides information on the identification of certain materials listed in the Federal Supply Classification (FSC) Groups 47 and 95, *Navy Stock List of General Stores;* the materials listed include nonferrous metal bars, ingots, pipes, tubes, and tubing. MIL–STD 183 and MIL–STD 184 contain information on the identification marking of iron, steel, and stainless steel products.

Other Methods for Identifying Metals

Color markings may become illegible or may be accidentally cut off. You will, therefore, need to know other methods for identifying metals. The various base metals, such as iron, copper, lead, zinc, and aluminum, have two identifying characteristics—SURFACE APPEARANCE and WEIGHT—by which persons who work with or handle these materials readily identify them. There are, however, a number of alloys which resemble each other and their base metal so closely that they defy accurate identification by simple means.

MAGNET TESTS, CHIP TESTS, and various ACID REACTION tests, in addition to the characteristics mentioned above, may be used as a means for identifying metals. The surface appearance of the more common metals and the reactions of these metals to the magnet and chip tests are listed in the table on pages 301 and 302. To use this table as an aid in solving a metal identification problem, you need good lighting, a small permanent magnet, access to a lathe, and a knowledge of what particular metals are in stock; this last item is particularly important since it will immediately reduce the number of possible identities. In connection with these tests, you will find the SPARK TEST, which is described in *Basic Hand Tool Skills,* NavPers 10085, very useful in making a final determination; it is especially useful in the case of alloys that contain nickel, and for all types of steels.

Data on Identification of Metals

Metal	Surface appearance or markings	Reaction to magnet	Lathe chip test
Aluminum	Light gray to white; dull or brilliant.	None	Easily cut; smooth long chips.
Brass	Yellow to green or brown	None	Smooth, long chips; more brittle than copper.
Bronze	Red to brown	None	Smooth, long chips; more brittle than copper.
Cast iron	Dark gray; evidence of sand mold.	Strong	Short, crumbly chips.
Copper	Smooth; red brown to green (oxides).	None	Smooth, long, pliable chips.
Copper-nickel	Smooth; gray to yellow or yellowish green.	None	Smooth, continuous chip.
Lead	White to gray; smooth, velvety.	None	(Cut by knife, any shape chip).

Data on Identification of Metals—Continued

Metal	Surface appearance or markings	Reaction to magnet	Lathe chip test
Magnesium Alloy	White; may have yellow-brown coating.	None	Short, easily cut chips.
Nickel	Dark gray; smooth; sometimes green (oxide).	Medium	Cuts easily; smooth, continuous chip.
Nickel-copper	Dark gray; smooth	Very slight at room temperature (Disappears if metal is heated above 200° F.).	Continuous chip; tough to cut.
Plain carbon steel	Dark gray; may be rusty	Strong	Varies, depending upon carbon content and heat treatment.
Stainless steel (18-8) (25-20)	Dark gray; dull to brilliant; usually "clean."	*None (faint, if severely cold-worked).	Varies, depending upon heat treatment.
Zinc	Whitish blue; may be mottled	None	Easily cut; short chips.

*** Stainless steels that have less than 26 percent alloying elements react to magnet.**

ADDITIONAL SOURCES OF INFORMATION ON METALS

If you desire additional information on metals, obtain a copy of the Navy training course, *Metalsmith 3 & 2*, NavPers 10565-B. That course provides more detailed information on metals, the methods of metal heat-treatment, and the methods of identifying metals; it also includes much information on metal-working operations. Information on piping materials and pipe-fitting operations is given in the Navy training course, *Shipfitter P 3 & 2*, NavPers 10592–B. See *Basic Hand Tool Skills*, NavPers 10085, for descriptions of the basic hand tool operations which are common to many of the metal-working and pipe-fitting operations which you may be required to perform.

QUIZ

1. What is meant by "factor of safety" of a metal part?
2. Define malleability.
3. What term best describes that property of metal which enables it to withstand shock, endure strains and stresses, and be deformed without breaking?
4. What is the basic distinction between ferrous and nonferrous metals?
5. What is the essential difference between carbon steel and alloy steel?
6. Name the two alloying elements upon which the grades of stainless steel are based.
7. Why is tungsten steel particularly good for cutting tools?
8. What effect does high temperature have on the strength of copper?
9. Upon what is heat treatment of metal based?
10. What heat-treatment process is used to relieve internal strains and induce softness in a metal?
11. What are the forms of heat treatment commonly used for ferrous metals?
12. Define critical temperature as it relates to metal.
13. When carbon tool steels are being hardened, what will be the result if quenching is too rapid?
14. When steel is being hardened, what quenching medium is used to reduce the warping tendency of the metal?
15. What process is used to relieve the strains which are brought about in metals during a hardening treatment?
16. When a metal is being case-hardened, what determines the depth to which carbon is absorbed?
17. What is essential if file hardness tests of various metals are to be of any value?
18. To what type of test is a metal subjected to determine the resistance of the metal to longitudinal stress or pull?
19. What test is used to measure the amount of bending back and forth that is necessary to bring a piece of metal to the breaking point without actual breaking taking place?

Items 20 through 37 (*Column A*) constitute a list of commonly used metals and alloys. The symbols for these metals and alloys are included in the list given in *Column B*. Match each item in *Column A* by selecting the proper symbol from *Column B*.

Column A	*Column B*
20. Aluminum	Mn
21. Antimony	Ce
22. Cadmium	Zn
23. Carbon	Al
24. Chromium	Cu
25. Cobalt	W
26. Copper	Sn
27. Iron	Me
28. Lead	S
29. Magnesium	Fe
30. Molybdenum	Ti
31. Nickel	Pb
32. Silicon	Ag
33. Silver	Mg
34. Tin	Si
35. Tungsten	Cd
36. Vanadium	C
37. Zinc	Ni
	Sb
	Be
	Cr
	V

38. What is indicated by the first digit of an S.A.E. steel specification number?

39. What is the carbon content of a steel identified as S.A.E. 3250?

40. What is the purpose of the magnet test, lathe chip tests, and acid reaction tests which are used on metals?

CHAPTER 9

MAINTENANCE OF GALLEY AND LAUNDRY EQUIPMENT

As a Machinist's Mate, you are well aware of your responsibility with respect to the operation and maintenance of machinery located within the engineering spaces of a ship. As you know, the Engineering Department is charged with the responsibility of maintaining machinery located outside of the engineering spaces; part of this machinery is located in the galley and laundry spaces.

RESPONSIBILITY FOR MAINTENANCE

Galley and laundry equipment is maintained in operating condition through the joint efforts of operating personnel and maintenance personnel. The extent of responsibility of operating personnel and that of maintenance personnel is determined by the officers responsible for the operation and maintenance of the equipment.

In general, the operator will keep the equipment clean, make minor adjustments related to the operation of the machine, and, in some cases, accomplish routine maintenance. When trouble occurs, the operator must determine whether electrical or mechanical equipment is involved. If mechanical equipment needs maintenance, it is the responsibility of the Machinist's Mate to make the necessary repairs, replacements, or adjustments. The

Machinist's Mate is also responsible for the performance of maintenance designed to prevent major breakdowns of mechanical components. Such maintenance must be performed at regular and frequent intervals.

A preventive maintenance schedule and checkoff list is established through the cooperation of the officers responsible for the operation and the maintenance of galley and laundry machinery. A program of preventive maintenance, particularly one where responsibility rests with two or more departments, will not succeed without full cooperation of all personnel concerned. When properly accomplished, preventive maintenance ensures the maintenance and repairs necessary to prevent major breakdowns.

In many cases, maintenance of galley and laundry equipment will require procedures with which you are already familiar. Much of the required maintenance will include the care of such equipment as pumps, valves of all types, and steam, water, and air fittings and piping, and the lubrication of machinery. A review of the chapters in this course and those chapters in *Machinist's Mate 3*, NavPers 10522, which deal with the equipment mentioned above should prove beneficial to you as you study about the maintenance of galley and laundry equipment.

GALLEY EQUIPMENT

A large number of different makes in each type of galley equipment is in use aboard ship. Because of the differences in machines which perform the same function, only general information is provided in this chapter. Detailed information on the maintenance of any piece of equipment should be obtained from the technical manual provided by the manufacturer or from instructions issued by the Bureau of Ships. In addition to general information on maintenance, a brief description of some galley equipment is included in this section to point out the principal component parts which you

may be required to maintain or to place in operating condition when troubles occur.

Most of the equipment used in the preparation of food and in the sanitizing of cooking utensils utilizes electrical power. The electrical components of such equipment are usually maintained by the Electrician's Mate. The mechanical components of the smaller machines used in the galley requires very little maintenance and that required will generally be performed by operating personnel. The Machinist's Mate will most likely be called upon to maintain larger items of galley equipment, many of which utilize steam as a source of heat. Such equipment includes steam-heated cooking equipment and dishwashing machines.

Dishwashing Machines

The Navy uses dishwashers of the single-tank and the double-tank types. Both types are available in manual and automatic models. One model of an automatic single-tank dishwashing machine is shown in figure 9–1.

Generally, single-tank machines are used only when, because of space and weight considerations, it is not practicable to use small double-tank machines. The single-tank machine contains one tank for warm wash water which is pumped and sprayed upon the dishes from above and below.

In single-tank machines the temperature of the wash water in the tank should be between 140° F. and 160° F. Rinsing is accomplished by means of hot water which is sprayed on the dishes from an outside source. The rinse water is controlled by an adjustable automatic STEAM-MIXING VALVE which maintains the temperature of the rinse water between 180° and 210° F. Washing and rinse sprays are controlled separately by automatic valves in the automatic machine, and by handles in the manually operated machine.

Double-tank machines of several sizes are in use. Ma-

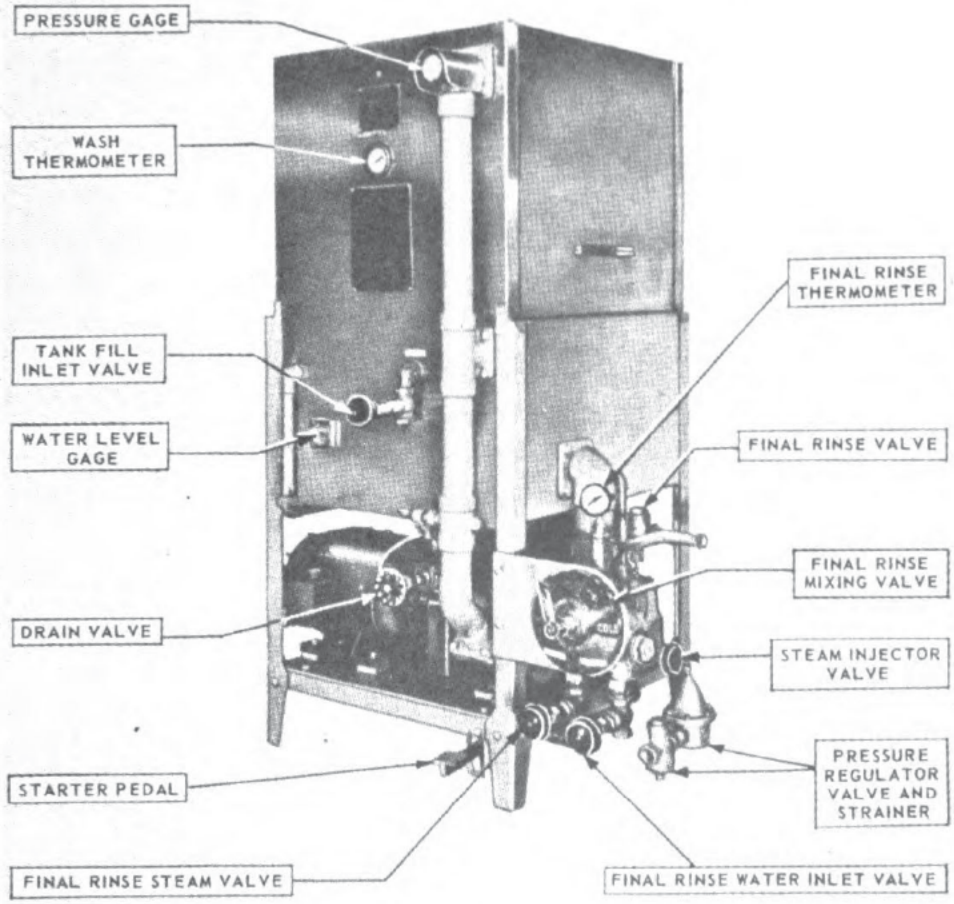


Figure 9–1.—Automatic single-tank dishwashing machine (model 50SA–7).

chines of the double-tank type are generally used when the utensils for more than 150 persons are to be washed. These machines are provided with separate wash and rinse tanks and a final rinse of hot water is sprayed on the dishes from an outside source. The final rinse is controlled by a self-closing valve which is opened by the baskets as they pass through the machine. The final rinse is fitted with an adjustable automatic steam-mixing valve which maintains the temperature of the rinse between 180° and 210° F. Double-tank machines are equipped with a thermostatically operated switch in the rinse tank which prevents operation of the machine when the temperature of the rinse water is lower than 180° F. Dish baskets are

passed through the machine automatically by means of CONVEYOR CHAINS.

MAINTENANCE OF DISHWASHING MACHINE.—If high health standards are to be maintained on board ship, it is essential that dishwashing machines be maintained in satisfactory operating condition. The machines should be inspected at regular intervals by maintenance personnel and repairs, replacements, or adjustments should be made whenever necessary. The following inspections should be made at least once a week:

1. Check the tension on the conveyor chains of machines so equipped; make adjustments if necessary. If both chains are equipped with lugs, see that these lugs are directly opposite each other.
2. Check to see that guide sprockets are located on their shaft so that the conveyor chain rides properly on the track assembly.
3. On single-tank machines, inspect the operation of the doors; be sure that all counterweights are properly attached and that they hold the doors in the open position when the doors are raised.
4. After the machine has been placed in operation in accordance with prescribed operating instructions, check the operation of all thermometers, pressure gages, and thermostats, and of the automatic mixing valve or booster.

   The thermostat on the rinse tank of a double-tank machine should be adjusted so that the machine cannot be started unless the temperature in the rinse tank is 180° F. or higher.

   The automatic mixing valve should be adjusted to maintain the temperature of the water at or above 180° F. when the rinse valves are open.
5. Inspect the pump packing and adjust it as necessary to stop leakage around the pump shaft.
6. Check the force of the recirculating wash spray.

   Hold a tray inside the machine so as to deflect the spray from the upper spray assembly further

into the machine; the lower spray, when not meeting the upper spray, should rise approximately to the top of the machine. If this is not occurring, there is insufficient spray velocity to produce satisfactory results. The cause of the trouble should be determined and corrected. The trouble may be due to any of the following causes:

a. Blocked pump-suction line.
b. Missing spray-tube cap.
c. Missing spray tube.
d. Jet orifices excessively worn.
e. Pump running backwards.
f. Pump impeller eroded.

7. Ascertain whether the conveyor on a conveyor-type machine is functioning in the proper manner.
8. Determine whether the final-rinse valve on a double-tank machine is functioning in a satisfactory manner; and whether, when the valve is opened, a uniform spray is coming from each of the orifices.
9. Clean the orifices of the spray valve if necessary.
10. Lubricate motor and pump bearings.
11. Check and lubricate, as necessary, the gear reducer unit.
12. Lubricate the conveyor-shaft bearings, drive mechanism, and sprocket chains.
13. Replace any missing lubrication fittings.
14. Inspect all steam and water valves.
15. Adjust gland nuts as necessary to prevent leakage.
16. Fill the tanks to the normal operating level, but do not open any steam valve; observe the water for a period of 5 minutes to determine whether there is an appreciable reduction in the water level. When there is an excessive reduction in the water level, check the drain valves for leakage.

17. Fill the tanks to the overflow opening and determine whether the overflow drain is functioning to prevent the water level from rising above the overflow opening.
18. Clean the drains and the overflow if necessary. The pumps should be disassembled and inspected at least once a year. Inspect the pump rotors to determine whether they are excessively eroded or corroded.

DESCALING OF DISHWASHING MACHINES.—Excessive scale deposit on the inside of piping and pumps clogs them and interferes with the efficient performance of dishwashing machines by reducing the volume of water that comes in contact with the utensils in the washing and sanitizing process. In addition, deposits within the machine provide an ideal place for dangerous bacteria to collect. Dishwashing machines should be descaled as often as necessary to prevent scale from interfering with the operation of the machine. The following method of descaling dishwashing machines may be used:

1. Fill the tanks half way to the overflow level with hot clean water.
2. To prepare the cleaning solution, add to the water in each tank 7 fluid ounces of orthophosphoric acid 85 percent and ½ fluid ounce of wetting agent for each gallon of water the tank will hold when it is filled to the overflow level. (When the capacity of a tank is not known, the inside dimensions (inches) of each tank may be used in the following formula to calculate the capacity in gallons; length times width times depth (to the water line) divided by 231 equals capacity in gallons.)
3. Complete the filling of the tanks to the overflow level.
4. With scrap trays, spray arms, and curtains in place, operate the machine for 30 minutes at the highest temperature possible.

5. Remove the cleaning solution completely by draining the tanks; rinse the tanks thoroughly by refilling them with fresh hot water and then operating the machine for five minutes. The rinsing procedure should be repeated several times.

LUBRICATION OF DISHWASHING MACHINES.—The points of lubrication and the schedule to be followed will vary depending on the type and design of each machine. The following schedule for one type of automatic double-tank dishwashing machine is typical:

1. Turn the grease cups on the pump-shaft bearings one or two turns each week. (If oil cups are installed, keep the cups near the overflow level.)
2. Check the level of oil in the speed-reducer case every three months. Oil should be added when the oil level is below the oil-level plug.
3. Turn the grease cups on the drive-end of the conveyor once a week and refill them when they are empty; if cups are not provided, oil the bearings with a few drops of recommended oil each day.
4. Turn the grease cup on the rinse lever once a week; refill the cup when it is empty.
5. Apply a few drops of oil to the revolving wash arm whenever the motor is oiled.
6. Oil should be placed in the cups on the motor once each week unless the bearings are of the ball type; some ball bearings need greasing once a year, others need no periodic lubrication. Check to be sure of the type of bearing in use.

CAUTION: A dishwashing machine must not be lubricated or repaired when the machine is in operation.

REPAIR OF DISHWASHING MACHINES.—To the extent that they are applicable, the general instructions listed below should be followed when dishwashing machines need adjustments or repair:

1. Repair strainer pans as soon as they are damaged or become defective; if pans are warped, straighten them so they lie flat in the machine.
2. Adjust the speed of the conveyor in automatic machines so that the washing and rinsing intervals are as recommended by the manufacturer.
3. Repair torn or worn curtains; replace them when they are beyond repair.
4. When the pump does not deliver enough water to the spray nozzles, remove the inspection plate and clean the pump housing. Impellers which are worn or damaged beyond repair should be replaced. Be sure the replacements have the correct dimensions and design.
5. When the packing around the pump shaft leaks, tighten the packing nut by hand. Do not use a wrench to tighten the packing nut; excessive tightening causes the packing to bind the shaft, which in turn overloads the motor and causes the packing to wear excessively.
6. Replace worn gland packing. Do not put more packing than necessary in a packing gland; excess packing will bind the shaft when the packing nut is tightened.
7. Replace damaged thermometers.
8. Make necessary adjustments and replacements on conveyors to ensure satisfactory operation.

   On some machines, the speed reducer for the conveyor is driven by a V-belt from the pump shaft. This belt will often stretch after the machine has been in operation for some time. To tighten the belt, first loosen the set screw on the outside portion of the belt pulley; then turn the outside half of the pulley so that the pitch diameter is changed sufficiently to tighten the belt. After the proper tension has been obtained, tighten the pulley setscrew.

9. Keep inspection doors on wash and rinse compartments watertight at all times. Leaks may result from a bent door; in such cases, straighten the door to make a tight fit. If the door still fits improperly, check the grooves in which the door slides and remove any accumulation of rust or other obstructions.
10. Check chains and pulleys of counterbalanced doors for defects. Oil moving parts and joints regularly to ensure smooth operation.
11. Repair dish racks as soon as defects are noted.
12. Adjust or repair steam coils, traps, and thermostats.

Steam-Heated Cooking Equipment

Much of the galley equipment which you will inspect and maintain utilizes steam as a source of heat. Some of this equipment, such as steam cookers, steam-jacketed kettles, and proofing cabinets, has few, if any, moving parts which require maintenance. In equipment of this type, your primary concern will be the maintenance of the valves and the piping which supply steam to the unit.

STEAM COOKERS (STEAMERS).—Some large galleys are equipped with a steamer that is used for cooking vegetables. Steam cookers are made of cast iron or steel, and have three or more compartments equipped with heavy doors operated by handwheels. Live steam that heats the steamer is controlled by a PRESSURE-REDUCING VALVE. Steam which does not condense escapes through the BLOW-OFF VALVE, and, in case of excess pressure, through the SAFETY VALVE. (See fig. 9–2.)

The doors of a steam cooker are of the full-floating type; that is, they are suspended on supporting arms which are hinged to the side of the cooker. The doors are closed by wheel-operated ball-bearing pressure screws on the door arms; the door arms apply equalized pressure at the center of the doors. When the doors are

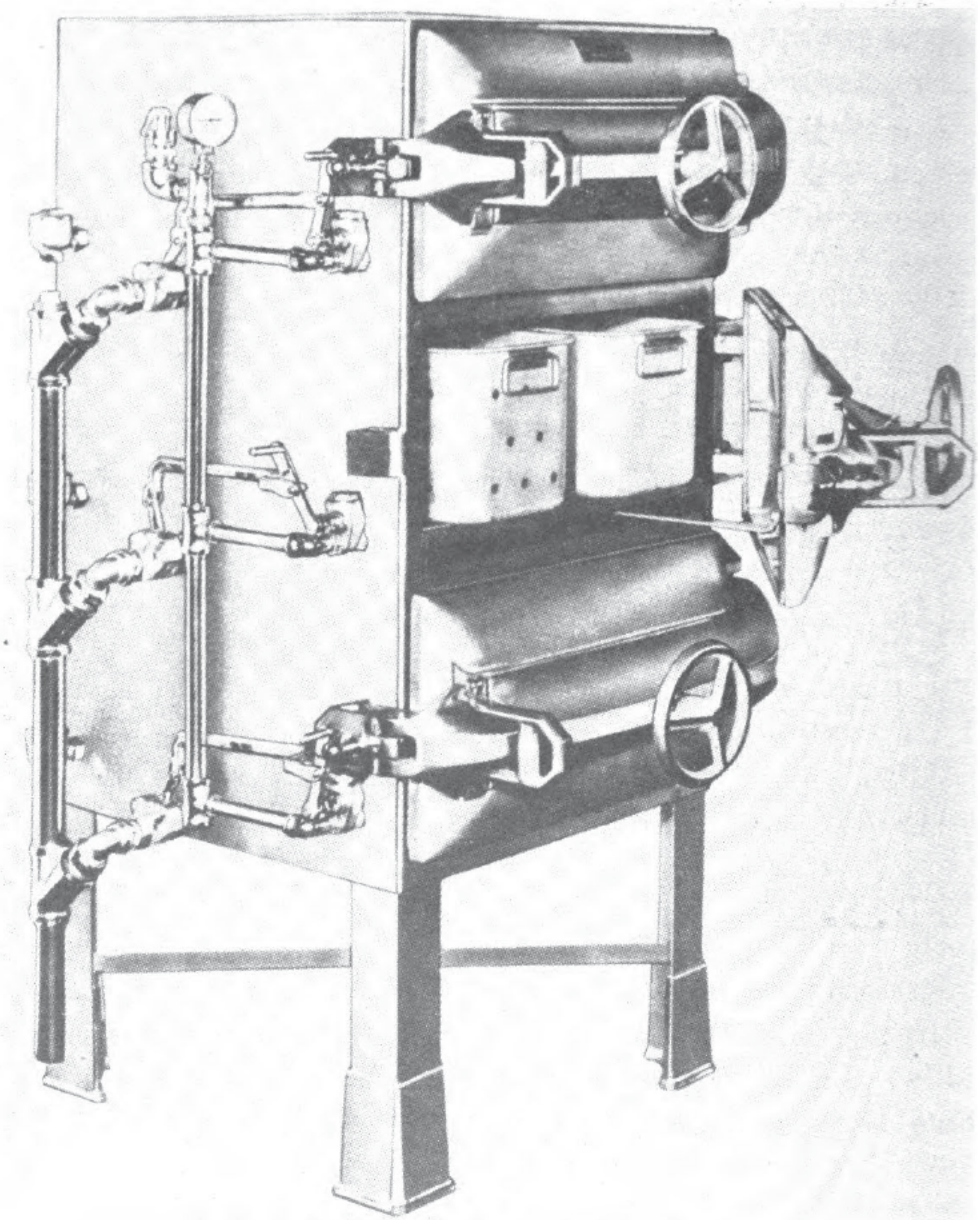


Figure 9–2.—Steam cooker.

closed, a seal is maintained by endless gaskets of special rubber composition.

Each compartment is supplied with steam through a quick-opening safety THROTTLE VALVE which is so arranged that the compartment doors cannot be opened

until steam is shut off. Each compartment is provided with a separate outlet and valve arrangement to prevent the intermingling of odors from various compartments.

An evaporating compartment is located under the steam compartments. The evaporating compartment is equipped with a STEAM COIL and STEAM-CONTROL VALVE, HAND WATER-FEED CONTROL VALVE, DRAIN VALVE, SAFETY VALVE and WATER-LEVEL GAGE. An access door is provided to facilitate cleaning of the evaporating compartment.

Steam cookers require a minimum of maintenance; the following items should be inspected, however, at the time intervals listed (unless otherwise specified by instructions issued by the manufacturer or the Bureau of Ships), and any necessary adjustments should be made.

Each WEEKLY INSPECTION of the cooker should include checking:

1. Operation of the pressure-reducing valve. Note the pressure setting of the gage on the low-pressure side; if the setting is incorrect, adjust it to the correct steam pressure.
2. Condition of the door hinges and the locking device, and operation of the shelf drawbar. Make adjustments whenever necessary.
3. Gaskets on the doors for steam leaks. Recement loose gaskets and replace worn and leaking gaskets.
4. Compartment drain for obstructions; be sure that the drain is clear.

The MONTHLY INSPECTION of steam cookers should include:

1. Observing the steam-gage reading. If there is any indication that the gage may be inaccurate, check it with a test gage. Examine the gage glass and replace it if cracks are found or if the glass is broken.
2. Checking the steam exhaust valves for proper operation and determining whether any steam is being bypassed. Make necessary adjustments.

3. Cleaning the strainers between steam compartments, and the thermostatic traps. Check the condition of the strainers and replace them if necessary. Clean the strainers ahead of the steam traps on all steam drips.
4. Checking the safety valve for obstructions. Test the valve for proper release pressure; if necessary, adjust the valve to release at the recommended pressure.

The following inspections should be made at least once during EACH QUARTER:

1. Clean drip traps of all scale and dirt. Check for steam leaks or steam bypassing the trap and repair the traps when necessary. If leaks or bypassing cannot be corrected, replace the trap.
2. Check the steam and return piping for leaks and for proper supports.

The following repairs, replacements, and adjustments should be made on steam cookers whenever necessary:

1. GASKET REPLACEMENT. Remove the door and place it on a work bench. Remove the old gasket and clean the channel thoroughly; take care not to chip or damage the channel.

Apply the recommended gasket cement, and insert the new gasket. Force the gasket into the channel at the corners and then work it towards the center of each end and side.

Rehang the door and close it lightly. Before closing the door tightly, place paper over the door opening to keep excess gasket cement from adhering to the mating surfaces of the door and cookers.

Leave the door closed until the cement sets. Clean off surplus cement.

2. DOOR-FIT ADJUSTMENT. Some full-floating doors are adjustable, others are not. When adjustment is possible, the doors and gaskets may be adjusted by turning the hexagon-head bolts which extend through the door, near each corner. When a replacement gasket is installed,

adjust the bolts so the closed door touches the body of the steamer evenly and does not bind at any corner. If the door is not adjusted properly, the gasket will be cut by the corners of the door.

3. LOCKING DEVICE ADJUSTMENT. If a plunger-type valve is used in conjunction with the locking device, adjust the plunger so that the valve is fully depressed when the door is closed and allows the full amount of steam to enter the compartment. Adjust the valve so it stops the steam supply completely when the steam door is opened.

4. STEAM VALVE REPAIR. When repacking a steam valve, install packing which fits, enters easily, and draws up evenly. When winding coil packing around the valve stem, force the packing to the outer edge of the stuffing box instead of wrapping it tightly around the valve stem; after adding the maximum number of packing rings, draw up packing gland evenly and make the nut hand-tight.

5. PIN AND BUSHING REPLACEMENT. The hinge pins and bushings of compartment doors should be replaced when they are excessively worn.

STEAM-JACKETED KETTLES.—Kettles were originally made of copper; they are now generally made of aluminum or corrosion-resistant steel. Kettles used by the Navy range in size from 10 to 80 gallons and are of the stationary type (see fig. 9-3).

The kettle illustrated is typical of most steam-jacketed kettles used by the Navy. The lower two thirds of the kettle is surrounded by a JACKET, which is set off from the main body of the kettle to provide space for steam to circulate and thus heat the contents of the kettle. Stationary kettles are mounted on three legs, have a HINGED LID, and a tube at the bottom of the body of the kettle with a DRAW-OFF FAUCET. The kettles are connected to an EXHAUST LINE which carries the vapor to the atmosphere, to a STEAM-INLET CONNECTION, and to a STEAM-OUTLET CONNECTION. A SAFETY VALVE is provided

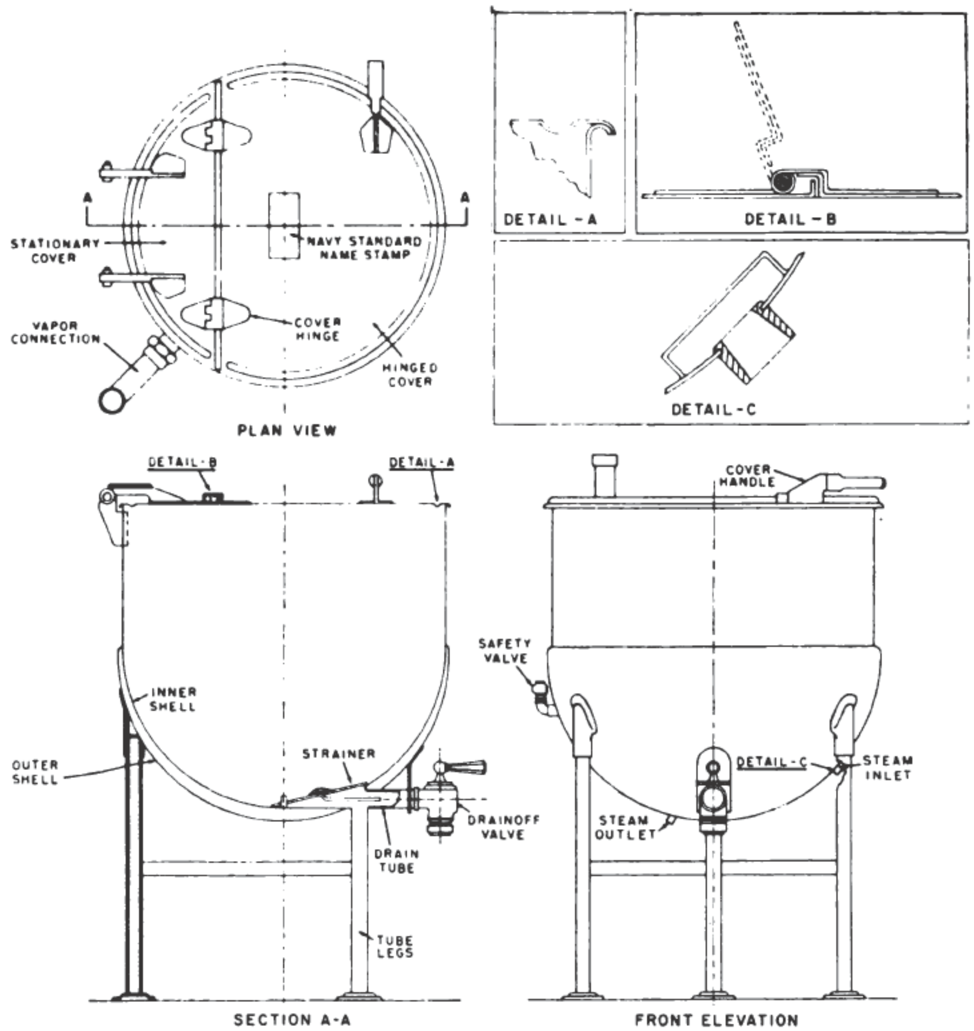


Figure 9–3.—Steam-jacketed kettle.

to release pressure from the jacket when the pressure exceeds the design limit. A GAGE should be installed to indicate the pressure in the steam line.

Most kettles are designed to operate on a maximum steam pressure of 45 pounds per square inch; some kettles, however, operate with a steam pressure of 80 pounds per square inch. If the steam line to the galley carries a pressure greater than that for which the kettle is designed, a PRESSURE-REGULATING VALVE is installed in the steam line leading to the kettles.

The inspections of the safety valve, the drip trap, the

steam piping, and the pressure gage of a steam-jacketed kettle are the same as the inspections of similar items on steam cookers. In addition to the inspections mentioned above, the following inspections should be made at the time interval indicated (unless otherwise specified by posted instructions).

The WEEKLY INSPECTION of a steam-jacketed kettle should include checking:

1. Operation and fit of the hinged cover. Adjust or repair as necessary.
2. Draw-off valve for leaks. Adjust or replace as necessary.

The following maintenance should be done during the MONTHLY INSPECTION of a steam-jacketed kettle:

1. Check the steam and water valves for leakage at the stems and seats. When leakage exists, tighten or renew the packing, or renew the seat. If this fails to stop the leakage, replace the valve.
2. Clean the inside of the water-gage glass; replace a cracked or damaged glass. Check the gage cocks for leaks; check to see that the cocks are free of sediment.
3. Drain and flush all sediment and loose particles of scale from the jacket.

The following maintenance should be performed when inspection of a steam-jacketed kettle reveals the need for such work:

1. Replace or reface the seats of steam valves and water valves when leakage appears.
2. If the kettle fails to heat when the steam valve is open, check the steam trap for obstructions and defects. If the kettle does not heat when the steam trap is in satisfactory condition, check the steam valve and the steam-supply line for defects.
3. If the draw-off valve leaks, dismantle it and clean it thoroughly. If trouble persists, grind the valve

seat with valve-grinding compound. Be sure to clean the valve thoroughly before it is reassembled. If the draw-off valve is damaged or worn beyond repair, replace it with a sanitary-type draw-off valve or a valve similar in design. Do not replace a draw-off valve with a conventional gate valve.

4. If the kettle remains hot when the steam valve is closed, check the valve for leakage; replace or reface the valve as necessary.

LAUNDRY EQUIPMENT

The laundry equipment which the Machinist's Mate may be required to inspect and maintain will include washing machines, extractors, tumbler driers, flat-work ironers, and laundry presses. (Descriptions of typical laundry equipment used aboard Navy ships are given in *Ship's Serviceman Laundry Handbook,* NavPers 10291.) Each piece of laundry equipment should be regularly inspected and maintained in accordance with the schedules and procedures outlined in the applicable technical manual. Adjustments, repairs, and replacements should be made as soon as possible after the need for maintenance is revealed by an inspection.

Inspection of Laundry Equipment

The details of an inspection schedule will vary depending on the model of machine being inspected and on the degree of responsibility assigned to the various persons charged with keeping the machine in efficient operating condition. Some of the items generally included in the inspection schedules of the equipment commonly found in the laundry spaces aboard ship are listed in the following paragraphs.

WASHING MACHINES.—The following inspections and adjustments should be made during the WEEKLY INSPECTION of washing machines:

1. Check all bearings and gearing, especially worm gearing, for excessive wear and other damage.

2. Check all gear-casing gaskets and stuffing boxes; they must be tight to keep water from entering the gear casing.
3. Check the mechanical condition and functioning of thermometers, water-level indicator, and timer, if fitted.
4. Check the tightness of steam valves and water-filling valves.
5. Check the tightness of the dump valve by filling the machine with water to the 6-inch level and determining whether, with all filling valves closed, water level drop more than one inch in ten minutes. An excessive rate of drop in water level indicates the need for valve repair or replacement.
6. Inspect the trunnion packing; adjust or replace as necessary.
7. Check the cylinder-door latches to determine whether they are functioning properly; latches should hold the door securely in both the open and closed positions. Latches should be kept as tight as possible at all times; looseness hastens wear of the cylinder door, door latches, and latch parts. Cylinder-door latches are of a tapered, self-adjusting type, and automatically compensate for wear within reasonable limits. When wear exceeds the range of automatic take-up, the latch-keeper must be readjusted.
8. Check the magnetic brake to determine whether it holds the cylinder securely in the proper position for unloading, and whether it releases properly when power is applied to the controller.
9. Determine whether the machine is running smoothly and whether it is reversing the direction of rotation in a regular periodic manner without excessive vibration or shock during reversals. Make any necessary adjustments in the tension of sprocket chains and belts. (The Electrician's Mate

will determine whether the adjustment of the timing-motor controller is correct.)

10. Check the operation of the shell-door interlock switch.
11. Check for any loose nuts, tap bolts, or screws; all such fastening devices should be fitted with lock washers or other suitable locking devices.
12. Inform the Electrician's Mate when faulty operation of the machine is believed to be caused by defective electrical equipment.

In addition to the items included in weekly inspections and to all checks and adjustments outlined in the maintenance section of the applicable technical manual, the following will be included in the SEMIANNUAL INSPECTION of washing machines:

1. Remove all gear guards, belt guards, and sprocket-chain guards.
2. Inspect all gears, sprocket chains, and belts for wear. Adjust the tension of sprocket chains and V-belts to ensure best performance. On a large machine driven by a sprocket chain on each end, the chains must be carefully synchronized and have the same degree of tension.
3. Check the trunnion bearings on each end of the shaft and all intermediate bearings for excessive wear; lubricate the bearings as necessary.
4. Clean all parts of the machine.
5. Replace the guards and make sure that all nuts, tap bolts, and screws are fitted with lock washers or other locking devices.

LAUNDRY EXTRACTORS.—The following inspections and adjustments should be made during the WEEKLY INSPECTION of laundry extractors (fig. 9–4):

1. Check the mechanical condition and the functioning of the cover safety interlock.
2. Check the adjustment on the pressure pads which support the spindle and basket.

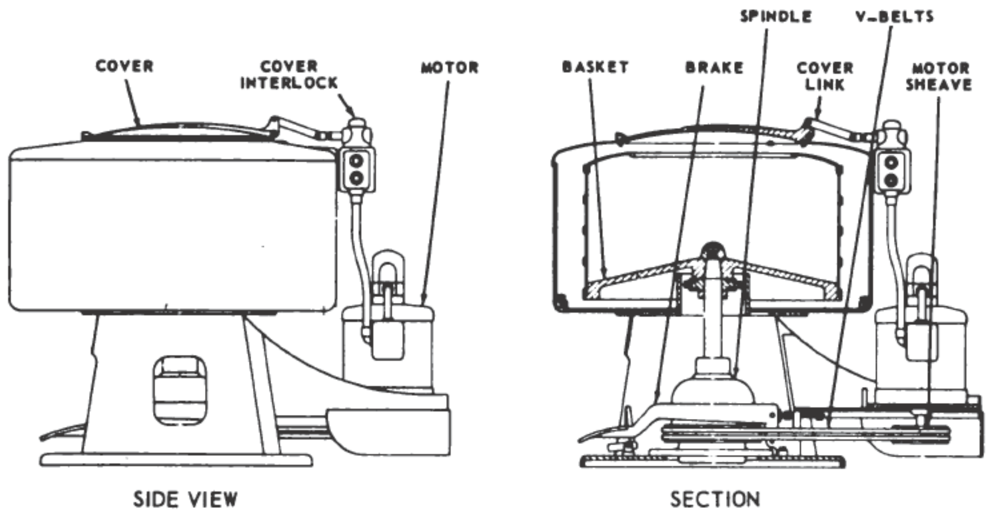


Figure 9–4.—Laundry extractor.

3. Check the bumper ring to determine whether it is in satisfactory condition and functioning properly
4. Check belt tension; adjust the belts as necessary.
5. Check the functioning of the brake; the brake should bring the extractor to rest within three-fourths of a minute after power has been interrupted and the brake applied.
6. Check the drain-line connection and be sure that it is open. When the connection is clogged, water will overflow around the spindle shaft and damage the drive mechanism.

In addition to all checks and adjustments recommended in the maintenance section of the manufacturer's technical manual, the following should be included in the SEMIANNUAL INSPECTION of laundry extractors:

1. Removal of the belt guard and examination of the belts; replace the belts if necessary.
2. Inspection of the basket and bands for possible defects. Particular attention should be given the strengthening bands; if defective, the bands may fail because of the high stresses imposed when the machine is operating at high speed.

The supporting flanges for the bearing housing of an extractor are mounted between rubber pads. The pads permit some oscillation of the extractor basket when the machine is in operation. The amount of oscillation is controlled by the pressure on the pads. A pressure nut is provided for making the necessary ADJUSTMENTS TO THE PADS. The pressure nut incorporates a locking set-screw which should be loosened before any adjustments are made. The set screw should be tightened when the adjustment is completed. A special spanner wrench is provided for turning the pressure nut. The pressure should be adjusted so that a 20-pound pull at the top of the basket will cause a movement of not more than one-eighth inch. In order to prevent excessive oscillation when the ship rolls the pressure must be maintained considerably higher than on extractors installed ashore.

Particular attention must be given to the INSPECTION OF BASKET BANDS. Rust may accumulate between the bands on the basket in such a way as to give the appearance of a double band in good condition; actually the metal may be greatly reduced in effective area and strength by corrosion. Special care is necessary to detect the true condition of the bands. Prod, scale, or take such other steps as are practicable to determine the condition of the strengthening bands. Should doubt arise as to the condition of the basket and the strengthening bands, steps should be taken to obtain a new basket. On recent extractors the baskets and reenforcing bands are made of corrosion-resistant metal.

TUMBLER DRIERS.—The following checks and adjustments should be made during the WEEKLY INSPECTION of tumbler driers:

1. Check the mechanical condition, and the functioning of the thermometer, if installed. (The thermometer is generally installed in the air-discharge duct leading from the tumbler cylinder.)
2. Check the tightness of all valves and the func-

tioning of steam traps to ensure that when the valves are open, the coils are uniformly heated.

3. Inspect steam heater-coils; clean the coils when necessary, using an air hose or an HVU blower with the vacuum attachment of an industrial-type vacuum cleaner.

   The heater coils of tumbler driers are generally arranged in two banks with separate steam connections to each bank. In most cases valves are provided on both the inlet and the drain side of each bank.

4. Remove the covers from all clean-out openings and clean all lint and dust from the machine and from the air-discharge ducts.

5. On end-loading tumblers, check the cylinder-door latches and determine whether the door is held firmly when it is in the closed position. On side-loading tumblers, check the cylinder-door latches and determine whether the latches hold the door securely in both the open and closed positions.

6. On side-loading tumblers, check the magnetic brake to determine whether it securely holds the cylinder in the proper position for unloading, and whether the brake releases properly when power is applied to the controller.

7. On side-loading tumblers, determine whether the machine is running smoothly and is reversing its direction of rotation in a regular periodic manner without excessive vibration or shock during reversals. Make any necessary adjustments in the tension of sprocket chains and belts.

8. On all side-loading tumblers check to determine whether all dampers are set so that there is no recirculation of air within the drier.

9. On side-loading tumblers, check the operation of the shell-door interlock.

In addition to the items included in the weekly inspections and the checks and adjustments outlined in the applicable technical manual, the following will be included in the SEMIANNUAL INSPECTION of tumbler driers:

1. Remove the guards and inspect all gears, sprocket chains, and belts for wear. Adjust the tension of sprocket chains and V-belts to ensure best performance. Replace parts which are worn excessively.
2. Check the trunnion bearings and all intermediate shaft bearings to determine whether there has been excessive wear; replace bearings when they are worn excessively. Lubricate all bearings as required.
3. Clean all parts of the machine.
4. Replace the guards; be sure that all nuts, tap bolts, and screws are fitted with the necessary lock washers or other locking devices.

FLAT-WORK IRONERS.—The following checks and adjustments are generally included in the WEEKLY INSPECTION of flat-work ironers:

1. Check the tightness of all valves and the functioning of steam traps; be sure that when the valves are open, the cylinder is uniformly heated.
2. Check the packing of the cylinder steam-joints and adjust as necessary to prevent steam leakage.

   The packing is held in place by a spring. If a joint shows more than a reasonable amount of leakage, check the packing for excessive wear. If the packing is not worn excessively, the packing spring may be broken.
3. Check the operation of the safety guard and the interlock switch.

At least twice a year, all gear guards, belt guards, and sprocket-chain guards should be removed from flat-work ironers. This is usually done at the time of the SEMIANNUAL INSPECTION. In addition to all inspections,

checks, and adjustments outlined in the applicable technical manual, the following are included in the semiannual inspection:

1. Inspection of all gears, sprocket chains, and belts for wear. Adjust tension of sprocket chains and V-belts to ensure best performance.
2. Checking the trunnion and roller bearings and all intermediate bearings to determine whether there has been any excess wear; lubricate the bearings as required.
3. Cleaning all parts of the machine.
4. Replacing all guards; make sure that all nuts, tap bolts, and screws are fitted with the necessary locking devices.

The steam cylinder of a flat-work ironer should be given an ANNUAL HYDROSTATIC TEST at the pressure recommended by the manufacturer.

LAUNDRY PRESSES.—Manual presses are used extensively in shipboard installations; some ships, however, are equipped with air-operated presses. In general, the WEEKLY INSPECTION of laundry presses will include the following checks and adjustments:

1. Check the mechanical condition of the machine to determine whether the head, when released, returns smoothly and without shock to the fully-open position; adjust counterbalance springs, shock-absorber cylinder, and air vent as necessary.
2. Fill the shock-absorber cylinder (if so equipped).
3. Inspect all valves to determine whether they are functioning without leakage.
4. Inspect the steam traps. If they are not functioning properly the head and buck will not be heated uniformly and there will be an excessive loss of steam.
5. On air-operated presses, make sure that neither of the air-control valves has been bypassed and that they are so adjusted as to require the use of both hands to close the press and apply pressure.

6. Check to determine whether excessive pressure is required on the foot pedal to lock the head in the pressing position. If excessive pressure is required, check for an excessive amount of padding; if the padding is satisfactory, check the linkage of the head pressure-mechanism.

The SEMIANNUAL INSPECTION of laundry presses includes all inspections, checks, and adjustments outlined in the applicable technical manual; and, on air-operated presses:

1. Removal and cleaning of all air filters.
2. Examination of the cups on the closing cylinders and pressure cylinders; replace the cups if they are badly worn.

All press-heads and bucks should be given an ANNUAL HYDROSTATIC TEST at the pressure recommended by the manufacturer.

Lubrication of Laundry Equipment

Lubrication is an important part of the weekly inspection of each piece of laundry equipment. The lubrication charts furnished with each piece of equipment should be checked for the location of lubrication fittings for the lubricants to be used. The location of the fittings as they appear on the chart for one type of flat-work ironer are shown in figure 9–5.

In general, all bearings and sliding surfaces of each piece of laundry equipment must be checked at least once a week and lubricated as recommended by the manufacturer of the machine. Oil and grease cups should be filled to the recommended level and grease should be added through all pressure grease fittings. All lubrication fittings should be checked; any fittings that are missing, damaged, or broken should be replaced. The sprocket chains of tumbler driers and washing machines are generally lubricated through drip-type oil cups; these cups should be kept full.

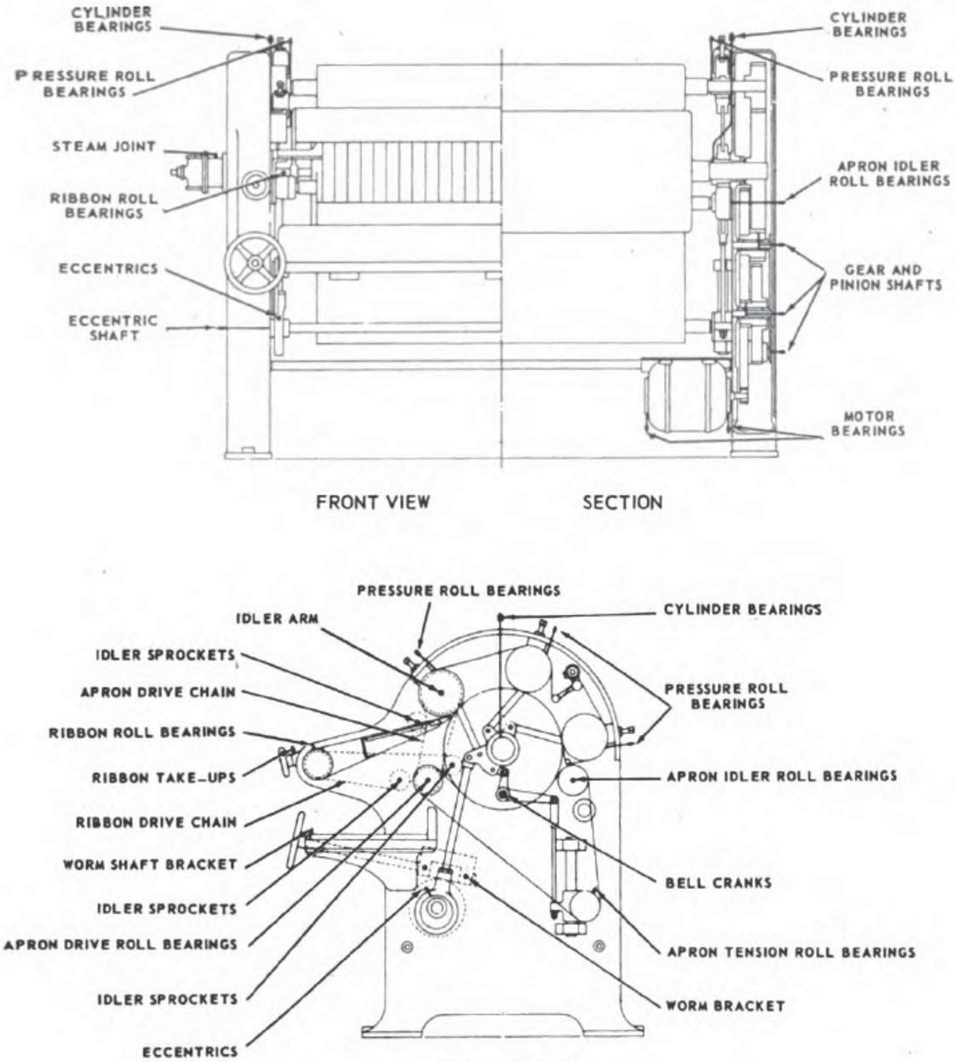


Figure 9–5.—Points of lubrication for a flat-work ironer.

Safety Devices on Laundry Equipment

Each piece of laundry equipment is provided with one or more safety devices. Since they are designed to protect the operator of the machine, safety devices must be maintained in proper working condition at all times. The inspection of safety devices is included as a part of the regular weekly inspection of laundry equipment. If a safety device is removed from a machine for any reason, the device must be replaced and be in satisfactory operat-

ing condition before the machine is again put in operation. Some of the safety devices which you may be required to adjust and maintain are described in the following paragraphs.

SAFETY INTERLOCKS.—The covers of laundry extractors are fitted with safety interlocks. The interlock is designed to keep the cover of an extractor from being opened while the basket is rotating, and to keep the machine from being started when the cover is open. On some recent extractors, there is an interlock between the brake and the safety switch; this interlock keeps the brake from being applied while the motor is energized, and keeps the machine from being started when the brake is set. In all cases, the STOP button should be operated to deenergize the motor before the foot brake is applied; and the foot brake must be released before the START button is used.

The cover safety-lock mechanism on laundry extractors includes a connecting rod which connects the portion of the interlock mechanism mounted on the top of the curb with the portion of the mechanism that is mounted underneath the curb. Generally, the components of interlock mechanisms will function reliably. The connecting rod between the portions of the interlock mechanisms may become bent, however, if considerable force is applied in opening the door of the extractor.

The connecting rod of an interlock mechanism should be checked regularly and frequently. If the rod is found to be bent or if there is an indication that the rod may become deformed when considerable force is applied in opening the cover of the extractor, a larger cold-rolled steel rod should be substituted for the original rod. For example, if a five-sixteenth-inch rod is in use, a one-half-inch rod will serve satisfactorily as a substitute. The ends of the substitute rod should be turned down and threaded to fit the presently installed clevises. If a larger rod is indicated but is not available, the existing rod should be straightened and a piece of close-fitting steel

tubing or iron pipe should be slipped over the rod to increase its stiffness.

The hinge pins and clevis pins of many safety-interlock mechanisms are held in place by cotter pins which can be removed readily. In order to make it more difficult for unauthorized personnel to disconnect the safety-interlock mechanism, upset or rivet as many of the pins as practicable.

Washing machines and tumbler driers of the side-loading type also are equipped with safety interlocks. On these machines the interlocks prevent starting the machine while the door in the outer shell is open; and, when the cylinder is in motion, they either stop the machine automatically when the door in the outer shell is opened or prevent the door being opened.

SAFETY GUARDS.—Flat-work ironers are always equipped with a safety guard or bar which extends along the front of the machine. The arrangement is such that the operator's hands will push the guard before they can enter the rolls of the machine. When the guard is pushed, a safety switch which stops the motor is activated. Some return-apron flat-work ironers have an added safety device which either applies a brake or declutches the motor when the safety guard is pushed. Safety guards should be inspected regularly and frequently; you must be sure that they are properly in place and performing their function. Safety guards which do not stop the motor when the guard is pushed must be adjusted or replaced before the machine is again operated.

All exposed gears, chains, and belts on laundry equipment are fitted with guards or shields. These guards must be in place and in satisfactory condition when equipment is put in operation.

PUSHBUTTON VALVES.—The two operating valves of air-operated laundry presses are of the pushbutton type. The arrangement of the valves is such that both hands of the operator must be used to operate the press; the hands of the operator, therefore, cannot be caught in the

press when it closes. The pushbutton valves must not be bypassed or left permanently open.

QUIZ

1. What trouble may exist if the doors on a single-tank dishwashing machine fail to stay open after they are raised?
2. What component of a dishwashing machine may be out of adjustment when the temperature in the rinse tank is less than 180° F.?
3. What are the possible sources of trouble when the force of the recirculating wash spray in a dishwashing machine is too low?
4. What should be checked for leakage when a test reveals an excessive loss of water from a dishwashing machine?
5. What may cause the water in a dishwashing machine to rise above the normal level?
6. How do scale deposits on the inside of piping and pumps reduce the efficiency of a dishwashing machine?
7. When the conveyor belt of a dishwashing machine becomes slack, how is the tension of the belt increased?
8. What may cause the inspection doors on the wash and rinse compartments of a dishwashing machine to fit improperly?
9. List five points on a steam cooker where repairs, replacements, or adjustments may be necessary.
10. What are the probable locations of sources of trouble when a steam-jacketed kettle fails to heat after the steam valve has been opened?
11. May a conventional gate-valve be used as a replacement for the draw-off valve of a steam-jacketed kettle?
12. What trouble must be eliminated when a steam-jacketed kettle remains hot after the steam valve has been closed?
13. Describe briefly how the tightness of the dump valve on a washing machine may be checked.
14. When should the latch-keeper on the cylinder door of a washing machine be readjusted?
    a. Weekly.
    b. When wear on the latch exceeds the range of automatic take-up.
    c. Monthly.
    d. When wear on the keeper is ⅛-inch or more.

15. What component of a laundry extractor may become damaged as a result of a clogged drain-line connection?

16. How can the pressure on the pads of a laundry extractor be checked?

17. Why is it essential to give particular attention to the inspection of the bands on the basket of a laundry extractor?

18. What is used to clean the steam heater-coils of a tumbler drier?

19. What would cause air to recirculate (an undesirable condition) within a side-loading tumbler drier?

20. What may be the cause of trouble when excessive leakage occurs at a steam joint on the cylinder of a flat-work ironer, if the packing is in good condition?

21. How frequently should the steam cylinder of a flat-work ironer and the head and buck of a laundry press be given hydrostatic tests?

22. What trouble may exist when excessive pressure is required on the foot pedal of a laundry press to lock the head in the pressing position?

23. What is the purpose of the safety interlock on a laundry extractor?

24. When the connecting rod of an interlock mechanism becomes bent and a replacement is not available, how may the rod be repaired?

25. What may be done to make the unauthorized disconnection of safety-interlock mechanisms difficult?

CHAPTER 10

ENGINEERING CASUALTY CONTROL

Upon the effectiveness of casualty control may depend the ship's ability to fulfill its prescribed mission. Regardless of the ship's inherent resistance to damage, her survival depends upon prompt and correct control action being taken when casualties occur. It is of vital importance, therefore, that you be fully aware of and trained for whatever action you may be called upon to perform in any possible casualty situation.

As a Machinist's Mate, you have learned that you are, directly or indirectly, concerned with operational and battle damage casualties which may occur in any of the engineering spaces; and that you are immediately concerned with casualties that may take place in the engineroom. You know the objectives of engineering casualty control, and how the methods of operating the engineering plant (split-plant operation and cross-connected operation) are used in connection with casualty control. You have had experience and training in the control of some casualties, and you know the procedures to be followed when those casualties occur. You are well aware of the fact that a complete and thorough knowledge of the engineering plant is essential if casualty control is to be effective. (See chapter 15, *Machinist's Mate 3,* NavPers 10522.)

Effective casualty control requires continuous and progressive training and experience on the part of all con-

cerned. As a Machinist's Mate 2, you must be able, when casualties occur, to assume responsibility greater than that required of the MM3. The information in this chapter will help you meet the training requirements in casualty control. In addition to the information in this chapter, you should be thoroughly familiar with *The Engineering Casualty Control Book* for the ship, the casualty control instructions contained in the ship's *Damage Control Book,* the ship's *Piping Systems Instruction Book* and the manufacturers' emergency instructions for the equipment or machinery that is on your general quarters station. These are the primary sources of information for your casualty control job.

The ability to perform the jobs necessary to restore damaged machinery to its original condition can be acquired principally through practical experience. Some information relating to the repair of machinery damage caused by casualties in the engineering spaces is given, however, in other chapters of this training course and in *Machinist's Mate 3,* NavPers 10522.

PREVENTIVE MAINTENANCE

Casualty prevention is the most effective form of casualty control. One of the principal factors which influence the effectiveness of casualty control is preventive maintenance. Preventive inspections and maintenance are vital to successful casualty control, since these activities minimize the occurrence of casualties caused by material failures.

Inspections

Detailed inspection procedures are necessary to discover damaged parts which may fail at a critical time. Inspections at frequent intervals make it possible to locate and eliminate conditions which may lead to early failure of a machine. Early failure may result from maladjustment, improper lubrication, corrosion, erosion, or other enemies of machinery reliability.

Symptoms of Operational Casualties

You must be on the alert at all times to detect even the most minor sign of faulty operation of machinery. Particular and continuous attention must be paid to the following external symptoms of internal malfunctioning of machinery:

1. Unusual noises.
2. Vibrations.
3. Abnormal temperatures.
4. Abnormal pressures.
5. Abnormal operating speeds.

You should become thoroughly familiar with the normal temperatures, pressures, and speeds of equipment specified for each condition of operation; departures from normal will then be readily apparent. It must not be assumed that an abnormal reading on a gage, or on any other instrument indicating operating conditions of machinery, is caused by an error in the instrument. Each such case should be investigated to establish fully the cause of the abnormal reading. Either the substitution of a spare instrument or a calibration test will quickly show whether an instrument error exists. Abnormal readings which are not caused by faulty instruments must be traced to their source, if preventive maintenance is to be effective. Some specific examples of advance warning of ultimate failure are outlined in the following paragraphs.

Because of the safety factor commonly incorporated in pumps and similar equipment, considerable loss of capacity can occur before any external evidence of trouble is readily apparent. In the case of pressure-governor-controlled equipment, changes in operating speeds from normal for the existing load should be viewed with suspicion. Variations from normal in chest pressures, lubricating-oil temperatures, and system pressures are indicative either of inefficient operating procedures or of poor condition of the machinery.

In cases where a material failure occurs in any unit, a prompt inspection should be made of all similar units to determine whether they are subject to the same type of failure. Prompt inspection may eliminate a wave of similar casualties.

Abnormal wear, fatigue, erosion, or corrosion of a part may indicate a failure to operate the equipment within its designed limits of loading, velocity, and lubrication; or it may indicate a design or material deficiency. After any of these symptoms has appeared, special inspections to detect damage should be undertaken as a routine matter, unless action can be taken which will ensure that such a condition will not recur.

Strict attention must be paid to the proper lubrication of all equipment; this will include frequent inspection and sampling to determine that the correct quantity of the proper lubrication is in each unit. It is good practice to take daily samples of lubricating oil from all auxiliaries. Such samples should be allowed to stand long enough for any water to settle. Where auxiliaries have been idle for several hours, particularly overnight, a sample should be drained from the lowest part of the oil sump. All settled water must be drained from the sump and the oil level must be brought back to normal by adding fresh oil. An unusual quantity of fresh water in the oil is normally indicative of either poorly fitted or worn carbon packing on the turbine-driven pumps handling fresh water.

Salt water may enter the oil from the salt-water pump glands, from the salt-water-cooled oil coolers, or from salt water dripping or spraying on the unit. The presence of salt water in the oil can be detected by drawing off the settled water with a pipette and then running a standard chloride test. A sample of sufficient size for test purposes can be obtained by adding distilled water to the oil sample, shaking vigorously, and then allowing the water to settle before the test sample is drained off. Because of its corrosive effects, salt water in the lubricat-

ing oil is far more dangerous to a unit than an equal quantity of fresh water. Salt water is particularly harmful to units with oil-lubricated ball bearings. When units with oil-lubricated ball bearings are found to be subject to salt-water contamination of the lubricating oil, it is essential that the oil be drained as soon as possible, that the bearings and sump be flushed thoroughly, and that the unit be refilled with fresh oil.

GENERAL PROCEDURES FOR CONTROL OF ENGINEERING CASUALTIES

The importance of engineering casualty control cannot be overestimated. Failure of any of the ship's normal services immediately reduces the vessel's resistance to damage, and impairs its ability to function effectively as either a fighting or auxiliary unit. The effects of engineering casualties are both direct and indirect. Directly, the casualties reduce the ship's mobility, offensive power, and defensive power; and its ability to control fire, flood, hull, and armament damage. Indirectly, the casualties reduce the ship's habitability and, thereby, lower the morale and efficiency of personnel.

It is quite easy for a single damaged unit in a machinery plant to disable the entire plant. A leaking condenser, for example, may disable both the boilers and the turbines. A damaged lube-oil line or pump, and the resulting loss of pressure, can also quickly damage the turbine and reduction-gear bearings. Prompt remedial action must, therefore, always be taken as soon as the casualty occurs.

The speed with which corrective action is undertaken in an engineering casualty is frequently of paramount importance. This is particularly true when such casualties affect propulsion power, steering, and electrical power generation and distribution. If casualties associated with these functions are allowed to become cumulative, they may lead to serious damage to the engineering installation—damage which often cannot be repaired without

loss of the ship's operating ability. Where the risk of developing permanent damage exists, the commanding officer has the responsibility of deciding whether to continue operation of the equipment under casualty conditions; such action can be justified only where the risk of greater damage, or even loss of the ship, might be incurred as a result of immediately securing the affected unit. For example, an entire plant might be operated with abnormal salinity present if such operation were necessary to enable the ship to steam clear of an area of possible enemy attack. However, all possible steps must be taken to shorten such a period of hazardous operation. It is reemphasized that whenever there is no probability of greater risk, the proper procedure is to secure the malfunctioning unit as quickly as possible, even though considerable disturbance to the ship's operations may result.

Although speed in controlling a casualty is essential, action should never be undertaken without accurate information; otherwise the casualty may be mishandled, and irreparable damage to the machinery and perhaps the loss of the ship may result. The cross-connecting of intact plants with a partly damaged one must be delayed until it is certain that such action will not jeopardize the intact plants.

Usually, each ship (or class of ships) has a specific casualty control procedure applicable to its own engineering plant. The procedure lists, in detail, the action to be taken in each space in the control of a particular casualty. Some typical engineering casualties and the general procedures recommended by the Bureau of Ships for their control are given in this section. As a Machinist's Mate 2, you are required to have a thorough knowledge of the action to be taken in each case.

Loss Of or Low Lubricating-Oil Pressure

Even a momentary loss of flow of lubricating oil to the bearings of a machine will result in localized overheating

and probably in slight wiping of one or more bearings. Damage can be prevented or minimized by stopping the shaft and quickly restoring the flow of lubricating oil. Continued operation with wiped bearings will cause serious derangement to the shaft packings, oil seals, and turbine blading.

The loss of lubricating-oil pressure may be caused by: (1) The failure of the system itself, including the main lubricating-oil pumps; (2) the failure of steam or electrical power supply to the main lubricating-oil pumps; or (3) damage to boilers, to steam lines, or to electrical equipment.

Component parts of the lube-oil system may fail because of the presence in these parts of dirt, rags, or other foreign matter. Failure of the system may be caused by a piping failure, by a failure of the operating pump, or by failure of the standby pump to start. Standby pumps should be maintained ready to start the moment the pressure drops below the prescribed operating range. If automatic-starting devices are not available on steam-driven pumps, the pumps must be lined up so that opening the throttle is the only action required to start the pumps. Steam-supply lines to standby pumps should be drained continuously. Where electrical pumps are installed, personnel must be thoroughly familiar with alternate sources of power.

A loss of steam pressure resulting from battle damage may be unavoidable. Split-plant operation is prescribed when maximum damage control is required to prevent total loss of power; therefore, cross-connection valves between split plants must not be opened until the damage is isolated.

A complete loss of steam pressure resulting from operational casualties, such as low water in boilers or water in the fuel oil, usually can be prevented if the throttleman closes the throttle as soon as possible and secures the auxiliary machinery that is not required. In this way,

available steam will be conserved for the lubricating-oil pumps and the vital auxiliary machinery. In addition, time will be provided in which to open the cross-connection valves.

The general procedure to be followed when lubricating-oil pressure is lost is as follows:

1. Upon failure of the oil pressure, immediately stop the affected shaft and simultaneously attempt to regain lubricating-oil pressure.
2. If steam pressure is available, stop the shaft by using the astern throttle. Engage the jacking gear and apply the brake. If the speed is in excess of one-half full power speed, stop the shaft by means of the astern turbine, slow down the ship to a safe speed, and then lock the shaft. Listen for, and attempt to locate, the source of any unusual or abnormal sounds. After the affected shaft is secured, the ship's speed may be increased to the limit for locked-shaft operation.
3. If steam pressure is lost in one engineroom during split-plant operation, take way off the ship by backing the other engine(s), unless the tactical situation positively prevents this action. Concurrently determine the nature of the casualty which is causing the loss of steam.
    a. If a loss of steam pressure in an engineroom will not cause a loss of steam to the other plant, open the auxiliary and the main-steam cross-connections immediately.
    b. If the damage is such as to cause a loss of steam to the other plant, isolate the damage; then open the auxiliary and the main-steam cross-connections as soon as possible.
    c. Stop and lock the affected shaft as soon as steam is available.
4. Concurrently, make every effort to regain the lubricating-oil pressure:

a. Check the lubricating-oil pump in use.
b. Start the standby pump (if it is not in operation).
c. Shift the duplex strainers.
d. Check the sump level. If it is low, replenish oil.
e. Locate and repair any leaks.

5. Concurrently with the above steps, inspect all bearings and endeavor to determine which have been overheated. Do not rely on thermometers alone (a thermometer may have indicated only a slight, momentary rise).

6. Secure the gland-sealing steam and the main air ejectors to minimize main-turbine rotor distortion.

7. Inspect and clean the lubricating-oil strainer basket which is not in use. Note whether flakes of bearing metal are present in the strainer.

8. Start the lubricating-oil purifier, if it is not already in use.

9. Continue circulation of the lubricating oil until the bearings are sufficiently cool for inspection. Circulate oil at all times, except when the bearings are actually being inspected, so that lubrication will be available if the shaft-locking gear should fail.

10. Take bearing-wear (micrometer) readings of all bearings and of axial clearances, where means for taking such readings are provided.

11. Proceed with the inspection of the bearings. Raise the bearing caps and roll out the shells. The inspection must be as thorough as circumstances will permit; the importance of subsequent reliable performance must be weighed against the time required for the inspection of suspected bearings.

12. Following a machinery derangement caused by the failure of the lubricating-oil supply, a thorough examination of the main reduction-gear bearings may be impracticable; however, the following information should be considered when such a casualty is being investigated:

   a. The oil-strainer basket in use should be examined for the presence of babbitt flakes.

   b. All turbine and cruising reduction-gear bearings should be thoroughly inspected. (In the event of loss of oil pressure, the cruising reduction-gear bearings are the first to be damaged.)

   c. The main reduction-gear bearings can be divided into 3 groups, in accordance with the rotational speed of the journals and the probability of the bearings becoming wiped. The rotational speed of the two high-speed pinions is the same as that of the respective turbine rotors. The speed of the bull-gear shaft is the same as that of the propeller shaft. The speed of the four intermediate-speed gear and pinion assemblies is approximately one-half the speed of the low-pressure turbine rotor.

   d. The high-speed pinion and the intermediate-speed pinion bearings of the main reduction-gear should be examined, through the inspection openings, for possible flow of babbitt from the bearings.

   e. Reduction-gear bearings thermometers should be loosened to check for oil flow from the wells. Absence of oil flow from the well, with the thermometer removed, indicates that the bearing may be wiped to the extent that the oil passage to the thermometer has been closed. When such a condition exists, a below-normal reading would be shown by the thermometer

when the shaft is operating. There may also be a stoppage of oil to the bearing.

f. If the turbine bearings are found to be in good condition, it can be assumed that the main reduction-gear bearings are also in good condition.

g. If a partial examination of the main reduction-gear bearings shows no indication of wiping and only one of the turbine and cruising gear bearings is found to be wiped, the shaft may be operated at the minimum speed which the tactical situation will permit until such time as a thorough examination of the main reduction-gear bearings can be made by a repair activity.

h. If several of the bearings for the high-pressure turbine, and especially those for the low-pressure turbine, are found to be wiped, it is likely that the high-speed pinion bearings for the main reduction-gear are also wiped. In this case, the shaft should not be operated until the high-speed pinion bearings have been thoroughly examined. If these bearings are wiped, the intermediate-speed gear and pinion bearing should be inspected. Whenever possible, these inspections and repairs should be made at a naval shipyard.

The above procedure applies when the lubricating-oil pressure of the entire system is lost. However, if it is noted that a turbine bearing is overheated because of a local loss of oil or because of the presence of foreign matter, and it becomes necessary to shut down the turbine, it should be slowed down, and kept operating at a slow speed, until the bearing and journal have cooled to a safe temperature. If the shaft is stopped quickly, the bearing metal may freeze to the shaft and thereby make repairs much more difficult.

Overheated Bearings and Their Treatment

An overheated bearing is a typical propulsion-plant casualty. The bearings of turbines, line shafts, and reduction gears are possible points of trouble. As a Machinist's Mate 2, you should have a knowledge of the action to be taken when any of these bearings become overheated.

TURBINE AND LINE-SHAFT BEARINGS.—When the temperature of a bearing exceeds its normal operating temperature, the following action should be taken:

1. Check to see that the proper amount of oil is being discharged from the cooler, and that an adequate supply of oil is being discharged to the bearings.

   The supply of oil may be increased by opening the needle valve, if a needle valve is provided; or by increasing the delivery pressure of the oil pumps, where this is practicable. The oil may be further cooled by increasing the flow of circulating water to the coolers. Only in an emergency may water be sprayed on an overheated bearing for the purpose of cooling it.
2. If these measures are not effective in reducing the bearing temperature, the speed of the unit should be reduced; in some cases, it may be necessary to stop the unit.
3. If overheating has not caused damage to shaft packings, overheated bearings may be operated at moderate speeds; however, the bearing should be replaced as soon as possible.
4. If bearing damage is believed to be excessive, turn the shaft at a slow speed until the bearing has cooled sufficiently to keep the bearing from freezing; then stop and lock the shaft. Continue the operation of the forced-lubrication system.
5. Operate the lubricating-oil purifier continuously to remove any flakes of babbitt or other foreign matter, which may be in the oil system.

REDUCTION-GEAR BEARINGS. — When reduction-gear bearings become overheated, do not operate the gear, except in an emergency, until the bearings have been examined. (See instructions in preceding section, LOSS OF OR LOW LUBRICATING-OIL PRESSURE.) Wiped bearings would permit pinion or shaft misalignment which, in turn, would result in uneven gear wear.

Cooler Tube Carries Away

When a tube of the lubricating-oil cooler carries away, the action to be taken is as follows:

1. If it is permissible to reduce the speed of the ship, bypass the cooler; and strike down oil from the storage tank to the sump to restore the working level.
2. If it is not permissible to reduce the speed of the ship sufficiently, or if the oil leak is not serious and there is an adequate supply of oil on board, increase the lubricating-oil pressure so that oil will leak into the waterside of the cooler; and pump make-up oil into the sump tank.

Lubricating-Oil Leak Into Engineroom

When lubricating oil leaks into the engineroom, the action to be taken is as follows:

1. If permissible, stop the engine.
2. If it is not permissible to secure the engine, plug or patch the leak (see *Machinist's Mate 3,* NavPers 10522) so as to stop oil loss and prevent the creation of a fire hazard.
3. Inspect the oil level in the sump; strike down purified make-up oil as necessary.

Excessive Oil-Pump Discharge Pressure

If the discharge pressure of the oil pump becomes excessive, the action to be taken is as follows:

1. Inspect the constant-pressure pump governor for proper operation.
2. Inspect the strainer and all parts of the lubricating-oil system for restrictions of oil flow. (See *Machinist's Mate 3,* NavPers 10522.)

Casualty to Deaerating Feed Tank (DFT)—Split-Plant

In the event of a casualty to a deaerating feed tank when steaming split-plant with all deaerating feed tanks in use, the following action should be taken:

1. Open to the unaffected plant the crossover valves in the condensate system, the main-feed system, the auxiliary exhaust steam line, the high-pressure drains, and the fuel-oil heater drains.
2. Secure the main-feed pump(s) and the booster pump(s).
3. Secure the exhaust steam to the damaged DFT.
4. Secure the high-pressure drains to the damaged DFT.
5. Secure the fuel-oil heater drains to the damaged DFT.
6. Secure the condensate-discharge valve to the damaged DFT.
7. Secure the recirculating system and all the vent valves on the damaged DFT.

Casualty to DFT—Cross-connected Plant

If a casualty to the DFT occurs when the ship is steaming with a cross-connected plant and has one deaerating feed tank in use, the following action should be taken:

1. Start the standby main-feed pump and the booster pump(s) in the opposite engineroom.
2. Secure the main-feed pump(s) and the booster pump(s) in the engineroom having the casualty to the DFT.
3. Secure the exhaust steam to the damaged DFT and route it to the opposite DFT.

4. Secure the high-pressure drains to the damaged DFT, and route them to the opposite DFT.
5. Secure the fuel-oil heater drains to the damaged DFT, and route them to the opposite DFT.
6. Secure all the vent valves and the recirculating valves on the damaged DFT.
7. Secure the condensate discharge to the damaged DFT, and discharge it into the opposite DFT.
8. Open the vent on the DFT being placed in service, and shift make-up feed to the opposite engineroom.

Low Water Level in Make-up Feed Bottom

When the water level in the make-up feed bottom drops below the suction piping, the following action should be taken:

1. Shift to another reserve-feed tank for make-up feed.
2. Refill the empty feed tank.

Low or Lost Main-Feed Booster Pump Pressure

The procedure to be followed when the main-feed booster pump pressure becomes low or is lost entirely, depends upon the cause of the casualty. Low pressure or loss of pressure may be caused by: (1) The sudden loss of deaerating feed tank (DFT) pressure; (2) the stopping or slowing down of the main-feed booster pump(s); (3) an empty DFT; or (4) an insufficient number of main-feed booster pumps in use. The steps to be taken in each case are listed in the following paragraphs.

SUDDEN LOSS OF DFT PRESSURE.—When the DFT pressure is suddenly lost, the following action should be taken:

1. Stop the main-feed pump(s) and the main-feed booster pump(s).
2. Start emergency-feed pump(s) on cold suction. (The emergency-feed pump can take a hot suction from the booster pump, or a cold suction from

the reserve-feed tanks. In standby condition, the emergency-feed pump should always be lined up on a cold suction.)

3. Bypass condensate to the reserve-feed bottoms by means of the excess-condensate return valve, if the water level in the DFT permits.
4. It may be necessary to reduce the throttle opening on the engine(s) to match the available feed supply to the boiler(s).
5. Build up the auxiliary-exhaust pressure by bleeding in make-up steam.
6. When the DFT pressure becomes normal: (1) Start the main-feed booster pump; (2) start the main-feed pump; (3) restore to their normal positions the valve(s) used in throttling condensate.

MAIN-FEED BOOSTER PUMP(S) STOPS OR SLOWS DOWN.—When pressure becomes low or is lost because a pump stops or slows down, the action to be taken will depend on the number of pumps in use. If all booster pumps are in use, the following action should be taken:

1. If a pump fails, slow engines to a speed where the remaining booster pumps can hold the required pressure.
2. If pump speed is not at rated value, adjust the speed-limiting governor.

If the only booster pump in operation is running slow, adjust the speed-limiting governor; if the pump fails, start an additional pump.

EMPTY DEAERATING FEED TANK.—When booster-pump pressure is low or lost because the DFT is empty, the following action should be taken:

1. Start the emergency-feed pump.
2. Stop the main-feed pump(s) and the main-feed booster pump(s).
3. Close the engine throttle until the emergency-feed pump can adequately feed the boiler.

4. Determine and eliminate the condition which caused the deaerating feed tank to become empty.
5. Refill the deaerating feed tank by taking on make-up feed or by transferring condensate from an adjacent plant. (During the refilling operation an adequate amount of heating steam must be supplied to the DFT.)
6. When the operating level is reached in the deaerating feed tank:
   a. Start the main-feed booster pump.
   b. Start the main-feed pump.
   c. Stop the emergency-feed pump.

When the above steps have been completed, the throttles on the engine(s) may be opened and speed may be resumed.

INSUFFICIENT MAIN-FEED BOOSTER PUMPS IN USE.—When pressure is low or lost because a sufficient number of pumps are not in use, the following action should be taken:

1. Start an additional booster pump.
2. Check to determine whether pumps were delivering rated capacity; and whether additional pump(s) were started when feed demand required them. (NOTE.—At all times the capacity of the booster pumps in use should exceed the capacity of the main-feed pumps in use.)

Unusual Noise From Pump End of Main-Feed Pump

When the main-feed pump is being started and unusual noise comes from the pump end, the following action should be taken:

1. Slow the pump.
2. Vent the pump end.
3. Check the main-feed booster pump discharge-pressure.
4. Add oil to the auxiliary oil reservoir of the thrust bearing.

Piping Casualties

The piping casualties discussed in this section are those which generally occur as a result of battle damage. In addition to the emergency restoration of interrupted services within the engineering spaces, the action required includes the isolation of damaged sections, the rigging and use of jumpers, and the patching or plugging of damaged piping.

RUPTURE IN FUEL-OIL TRANSFER LINE.—When this casualty occurs, the following action should be taken:

1. Stop the transfer pump.
2. Isolate the damaged section of the line.
3. Use the transfer line on the opposite side of the ship, if fitted; if the ship is not fitted with an additional transfer line, patch rupture.
4. Restart the transfer pump.

RUPTURE IN FIRE-MAIN PIPING BETWEEN PUMP AND FIRE MAIN.—When a rupture occurs in the fire-main piping between the pump and the fire main, the following action should be taken:

1. Close the cut-out valves located where the pump-discharge line joins the fire main.
2. Close the pump discharge valve.
3. Stop the pump.
4. When another pump is available, place it on the line.
5. If another pump is not available, a jumper can be run between broken sections of the fire main; or a hose can be run between fire plugs on either side of a damaged section. A portable gasoline-driven fire pump or electric submersible pump can be connected to discharge to the fire main.

RUPTURE IN SALT-WATER COOLING SERVICE PIPING.—When this type of casualty occurs, jumpers of hose can be rigged in the system; and hoses can be run directly from undamaged sections of the system to units which

require cooling water. Damaged sections of piping should be isolated and patched or plugged.

Steering Gear And Propeller Casualty—Near Miss

In the event of a steering gear and propeller casualty, the engine(s) should be stopped and the type of damage determined. The action to be taken will depend upon the type of damage:

1. If the electric power supply to the steering gear is damaged, a casualty power cable must be rigged.
2. If steering motors are damaged, shift to the emergency-steering unit or steer with main engines.
3. If oil lines are ruptured, patch them; or replace them, if possible.
4. If a propeller is beyond repair, lock the shaft and proceed on the other engine.

QUIZ

1. How does preventive maintenance aid in the control of casualties?
2. List five external symptoms which indicate that a machine is not operating properly.
3. When a material failure occurs in any unit, what should be done to all similar units? Why?
4. What trouble is indicated by an unusual quantity of fresh water in the lubricating oil of a turbine-driven fresh-water pump?
5. How may the presence of salt water in the lubricating oil of an auxiliary be detected?
6. Who has the responsibility of deciding whether to continue the operation of equipment under casualty conditions, when such operation may result in permanent damage to the equipment?
7. What is the only justification for continued operation of machinery under casualty conditions, when the risk of permanent damage to the machinery exists?
8. What is the first step to be taken when loss of lubricating-oil pressure occurs?
9. What bearing condition is indicated by a below-normal reading (during operation) on the thermometer of a reduction-gear bearing?

10. What should be done before a turbine with an overheated bearing is secured? Why?
11. When a shaft is stopped and locked because of an overheated bearing, what action should be taken with respect to lubrication?
12. How do wiped reduction-gear bearings lead to uneven gear wear?
13. What action should be taken when the tube of a lubricating-oil cooler carries away, and a reduction in speed is not permissible?
14. What action should be taken when a lubricating-oil leak develops in the engineroom, and it is not permissible to secure the engine?
15. What may be the trouble if the discharge pressure of the lubricating-oil pump becomes excessive?
16. When a ship is steaming split-plant with all deaerating feed tanks (DFT) in use and a DFT casualty occurs, what cross-over-valves are opened?
17. List four possible causes for the main-feed booster pump pressure becoming low or lost.
18. When main-feed booster pump pressure becomes low because of the sudden loss of DFT pressure, how is auxiliary-exhaust pressure increased?
19. Upon what will the action to be taken depend when main-feed booster pump pressure decreases because of a decrease in pump speed?
20. As a deaerating feed tank is being refilled, what action should be taken when the operating level is reached?
21. What action should be taken with respect to the main-feed pump when unusual noise comes from the pump end?
22. What valves should be closed when a rupture occurs in the piping between the pump and the fire main?
23. What is used to restore service when a rupture occurs in the salt-water cooling service piping?
24. How may steering be accomplished when a steering-motor casualty occurs?

APPENDIX I

ANSWERS TO QUIZZES

CHAPTER 1

PREPARING FOR ADVANCEMENT TO MM2

1. The general service rating, MM.
2. To provide broadly qualified, versatile personnel who, in time of emergency can be advanced to positions of greater responsibilities and authority.
3. Machinist's Mates L (General Machinist's Mates), Machinist's Mates R (Refrigeration Mechanics), and Machinist's Mates G (Gas Generating Mechanics).
4. The *Manual of Qualifications for Advancement in Rating,* NavPers 18068, Revised.
5. By study.
6. The *Military Requirements for Petty Officer 3 & 2,* NavPers 10056.
7. Be sure that the publication is the most recent edition available.
8. To catch mistakes before they result in excessive loss of time, labor, and material.
9. By tying new material in with what the individuals already know, and by showing them how the new material relates to their duties.
10. The shorter periods produce less monotony and fatigue.

CHAPTER 2

ENGINEROOM OPERATING PROCEDURES

1. To prevent leaks at the joints.
2. Opening the drains.

3. One hour, unless instructions indicate otherwise.
4. By use of the centrifugal purifier preheater, by use of auxiliary-exhaust steam in the lube-oil cooler, or by heating in the settling tank.
5. To prevent the leakage of salt water into the oil, in case the cooler is leaking.
6. The second stage is placed in operation just prior to, or simultaneously with the admission of steam to the gland sealing system; the first stage is cut in just before the engineering department is reported ready for getting under way.
7. Unequal expansion will take place and cause distortion of the rotor or the casing or both.
8. Just before the turbine rotor is revolved by jacking or spinning.
9. The astern valve should be opened first. This is done so that any condensate remaining in the steam line may be discharged through the larger nozzles and the fewer rows of blading of the astern turbine.
10. When puffs of steam are admitted to the turbine the rotors start more quickly and are less likely to heat unevenly.
11. Close the drains to the condenser; bring the pressure of the gland steam between ½ and 2 psi above atmospheric pressure; and spin the rotor, alternately astern and ahead.
12. Stop the turbine and restore lubricating-oil flow.
13. Search for leaks, look for open drains and valves, check to see that the overboard discharge is wide open, and open the valve on the condenser head to make sure the condenser is not air-locked.
14. To prevent the leakage of air into or the leakage of steam from the turbine.
15. So the condenser can evacuate the cruising turbine.
16. Either unequal heating of the rotor or an accumulation of water in the turbine.
17. To maintain the pressure in the steam chest as high as practicable.
18. To ensure uniform stresses in the turbine blades.
19. A finger piece, a rotor-position micrometer, or a clearance indicator.

20. Avoid long or hard contact of the micrometer spindle with the rotating shaft. This is done to prevent the end of the spindle from becoming worn.
21. Open.
22. No.
23. Rapid and excessive lowering of steam pressure, and priming.
24. (c) Secure steam to first stage air ejector.
25. One hour.

CHAPTER 3

TURBINES AND AIR EJECTORS

1. The angle at which the steam hits the moving blades and the shape of the moving blades.
2. The nozzles.
3. Only in the nozzles.
4. The inverted circumferential dovetail methods differ from the circumferential dovetail method in that the dovetail in the former is machined into the root of the blade rather than into the rotor or casing.
5. As re-entry turbines.
6. A throttle valve, nozzle control valves, and bypass valves.
7. Modern control mechanisms combine, in a single handwheel, the operation of the throttle, the nozzle control valves, and the bypass valves.
8. To attain the optimum rates of blade speed to steam speed at or near cruising speed.
9. Cruising turbines are smaller in size and are not fitted with bypasses.
10. Hydraulically.
11. It is designed to operate on either saturated or superheated steam (both).
12. The overspeed trip.
13. To operate a pilot valve which controls the flow of oil to the operating cylinder.

14. When the turbine tends to slow down because of an increased load on the generator.
15. Because the turbine is subject to variable expansion resulting from changing temperature and load conditions.
16. 180° F.
17. Care must be taken that steam does not bleed into the turbine casing.
18. By the main bearings.
19. To prevent damage to the turbine.
20. Once each quarter.
21. The surfaces should be restored by the use of a very smooth oil stone moistened with kerosene.
22. At least once each month, when new; thereafter, every six months.
23. The foreign deposits should be carefully removed by using nozzle reamers or a soft copper wire.
24. Plans and manufacturers' technical manuals should be consulted.

CHAPTER 4

PUMPS, VALVES, AND PIPING

1. Operating the pump at full stroke.
2. Long stroke.
3. By means of tappet collars.
4. By jacking the pump with a bar.
5. A valve may be broken.
6. Assemble all the pertinent blueprints, drawings, and available data.
7. Poor workmanship and assembly, or the rod is so fitted that the shoulder bears against the piston without giving a proper bearing surface for the tapered part of the rod.
8. Soak the packing in hot water for at least 12 hours.
9. Faulty piston rings.
10. Fit the new rings to the cylinder to check the gap clearance.

11. Rotary pumps are designed with very small clearances between rotating parts and between rotating and stationary parts.
12. Do not install the new bearings without spotting them in, or checking and fitting them to the designed clearance.
13. The gears must be securely locked to the rotor shafts in their exact designed position.
14. Once each quarter.
15. Lack of proper lubrication.
16. The pump should be opened and repaired as necessary.
17. To prevent the necessity of renewing an entire shaft solely because of wear in the packing gland area.
18. To offset the need for renewing or making extensive repairs to the casing and impeller.
19. It is keyed in with headless screws.
20. Too much clearance will let an excessive amount of liquid leak back from the discharge side to the suction side of the pump.
21. At least every 6 months.
22. Remove the upper half of the bearing.
23. If the concentricity of a bearing is lost, the pump shaft may become misaligned. This not only causes unequal loads on the bearings along the shaft, but also tends to destroy the clearances between the casing and impeller wearing rings.
24. Short in capacity.
25. Pump overloads the driver.
26. Casing rings and impeller rings, shaft sleeves, bearings, and bushings.
27. The valve should be made tight by grinding the disk together with the seat.
28. With the valve stem pointing upward.
29. A sticking valve stem.
30. Salt-water lines.
31. They should be refaced either in a lathe or with a reseating machine.
32. Once each quarter.
33. Graphite or asphaltum paint.

34. A dangerous blowout may result from progressive growth of the leak.
35. The piping should be removed and the defect closed by brazing.
36. With sheet lead or with some other soft metal.
37. Copper-nickel alloy piping.

CHAPTER 5

OPERATION AND MAINTENANCE OF REFRIGERATION EQUIPMENT

1. Open.
2. "Manual."
3. To enable the operator to determine whether or not the compressor is operating properly.
4. The suction pressure and the pressure in the compressor crankcase.
5. By manipulation of a valve in the overboard line from the condenser.
6. The compressor should be stopped with the manual control.
7. Increasing the range between the cut-in and cut-out points of the low-pressure control switch; reducing the capacity of the compressor.
8. Alternating operation.
9. One-fourth inch.
10. (1) Shut off the supply of Freon to the coil to be defrosted, and (2) allow the temperature of the compartment to rise above 32° F.
11. The entrance door to the compartment is left open.
12. It permits defrosting the coils with the plant in operation and without elevating the compartment temperature.
13. To eliminate the possibility of liquid slugs being returned to the compressor.
14. Enough refrigerant must be immediately bled into the evacuated part of the system to raise the pressure between one-half and 2 psi.

15. The fact that frost no longer forms on the liquid line.
16. The service drum is cooled thoroughly in an ice-water bath before the drum is connected to the refrigerant system.
17. By slowly flushing refrigerant through the line before it is connected to the drum.
18. The drum is weighed.
19. (1) Use of a halide leak-detector; (2) use of soapsuds.
20. The flame will remain blue if no Freon is present; if Freon is present, the flame will take on a greenish color. The shade of green will depend upon the concentration of Freon-12 present.
21. To allow for the time lag between the moment when air enters the tube and the moment when the air reaches the reactor plate of the detector.
22. Soapsuds.
23. The loss of refrigerating effect.
24. When there is a difference of about 5° F. between the condensing temperature of pure Freon-12 and that of the Freon-12 in the system.
25. By opening the discharge-pressure gage connection.
26. Air lance, water lance, rotating-bristle brush, soft rubber plugs, and an air or water gun.
27. The extent of deterioration.
28. Solder.
29. Paint.
30. Service experience.
31. The system.
32. A gradual and progressive decrease in lubricating-oil pressure.
33. Colorless, odorless, nonpoisonous, nonexplosive.
34. Boiling point.
35. Check all identification marks on the cylinder.

CHAPTER 6

STEAM-OPERATED DISTILLING UNITS

1. (d).
2. (b).
3. Distillate cooler, distiller condenser, after condenser, and vapor feed-water heater.
4. By centrifugal force.
5. To supply heat to the first-effect feed and to the brine in the second effect; and to form, as it condenses, part of the distillate.
6. (a).
7. The pressure differential between the two components.
8. (b).
9. Either a drain controller, or a recirculating line and throttle valve.
10. A solenoid dump valve is actuated by the salinity cell and the contaminated output is discharged to the bilge until the unit can be secured and the cause of high salinity eliminated.
11. It removes noncondensable gases.
12. Distiller condenser.
13. The pressure in the flash chambers, which is lower than the saturation pressure corresponding to the temperature of the hot feed.
14. Feed-inlet box, vapor separator, and distilling condenser.
15. Removable.
16. (c).
17. On the shell side of the distiller condenser.
18. To maintain the required level in the suction line between the salt-water heater and its drain pump.
19. First-stage distillate drain regulator.
20. Distillate outlet of the distillate cooler; distillate inlet of the distillate cooler; distillate drains from the first-stage distiller condenser; discharge of the salt-water heater drain pump; and the drain line of the air-ejector condenser drain.
21. It causes the solenoid of the three-way trip valve to be de-energized when salinity exceeds 0.065 epm and thus trips the valve.

22. No.
23. (a).
24. Air.
25. Ship's condensate system.
26. Distillate cooler.
27. Pressure differential.
28. Second-stage distiller condenser.
29. Salt-water leakage from the evaporator shell into the tube nest.
30. By hydrostatic test.
31. The orifices in the first-stage feed box are fouled.

CHAPTER 7

HYDRAULIC AND PNEUMATIC EQUIPMENT

1. The direct-plunger lift and the plunger-actuated cable lift.
2. Automatic quick-closing valves in the hydraulic fluid line.
3. The platform.
4. By means of manually operated locks, or platform locks.
5. The safety-cam assembly.
6. The operation of the elevator is controlled from either the platform pushbutton station or from the handwheel at the hangar-deck control station.
7. The main pump (main hydraulic pump).
8. By means of the stroke regulator handwheel.
9. The compensator automatically sets the pump at zero stroke when the pressure in the high-pressure tank reaches 740 psi.
10. To control the flow of oil to and from the elevator cylinders.
11. The terminal stopping device.
12. A combination spline coupling.
13. The hand-control station at the hangar deck.
14. An interference switch.

15. Lower the platform to the hangar deck. Close the pressure tank valve, the exhaust tank valve, and the strainer valve.
16. With the platform locked at the flight deck, close the pressure tank valve, the exhaust tank valve, and the strainer valve.
17. The continuous use of such material tends to cause an accumulation of lint in the system.
18. The torque equalizer automatically reduces the pump stroke in order to prevent the motor from being overloaded.
19. To limit the movement of the steering wheels to the equivalent of the hardover to hardover rudder movement.
20. To bring a stalled rudder to a center position where it will least interfere with the steering of the ship by the other rudder.
21. To provide emergency steering by either electric motor or hand power, in the event of failure of the main system.
22. About every 6 months.
23. The discharge valve is defective.
24. Dirty intake air, excessive use or improper grade of cylinder oil, or excessively high air temperature resulting from faulty cooling.
25. Make certain that the suction valves open TOWARD, and the discharge valves AWAY FROM, the center of the cylinder.
26. Solder or fuse.

CHAPTER 8

METALS AND THEIR PROPERTIES

1. The ratio that ultimate strength bears to working stress.
2. Malleability is that property of metal which permits it to be hammered or rolled into thin sheets.
3. Toughness.
4. Ferrous metals are those metals the major portion of which is iron; nonferrous metals contain either no iron, or only a small amount of iron as an impurity.
5. In carbon steel, the alloying element is carbon; in alloy steel, alloying elements in addition to carbon are used.

6. Chromium and nickel.
7. Because it retains its hardness at high temperatures.
8. Copper's strength decreases rapidly when the temperature rises above 400° F.
9. On the effect that rate of heating, temperature to which the metal is heated, and rate of cooling have on the molecular structure of metal in its solid state.
10. Annealing.
11. Annealing, normalizing, hardening, tempering, and case-hardening.
12. The temperature at which change in structure and in other physical properties takes place.
13. The metal will warp and crack.
14. Oil.
15. Tempering.
16. The length of time the metal is left in the oven.
17. File hardness tests of various metals must be made at the same speed and with the same pressure.
18. Tensile test.
19. Fatigue test.
20. Al
21. Sb
22. Cd
23. C
24. Cr
25. Co
26. Cu
27. Fe
28. Pb
29. Mg
30. Me
31. Ni
32. Si
33. Ag
34. Sn
35. W
36. V
37. Zn
38. The type of alloy.
39. 0.50 percent.
40. To identify the individual metals.

CHAPTER 9

MAINTENANCE OF GALLEY AND LAUNDRY EQUIPMENT

1. The counterweights may be attached improperly.
2. The automatic mixing valve.
3. Pump, spray tube, or jet orifices.
4. Drain valves.
5. Clogged overflow-drain.
6. Excessive scale reduces the volume of water that comes in contact with the utensils in the washing and sanitizing process.
7. By changing the pitch diameter of the belt pulley.
8. The doors may be bent, or the grooves in which they slide may contain rust or other obstructions.
9. Door gasket; door fit; locking device; steam valve; and hinge pins and bushings.
10. Steam trap, steam valve, and steam-supply line.
11. No.
12. Leakage at the steam valve.
13. Fill the machine with water to the 6-inch level; close all filling valves and observe the water level for 10 minutes. If the level drops more than one inch in that time the dump valve needs repair or replacement.
14. (b).
15. The drive mechanism.
16. By applying a 20-pound pull at the top of the basket and determining the amount of movement; movement should not exceed ⅛-inch on shipboard installations.
17. Because the metal, while appearing in good condition, may be greatly reduced in effective area and strength by corrosion.
18. An air hose, or an HVU blower with vacuum attachment.
19. Improperly set dampers.
20. A broken packing spring.
21. Annually.

22. The amount of padding used may be in excess of that required, or the linkage of the head pressure-mechanism may be out of adjustment.
23. The interlock is designed to keep the cover from being opened when the machine is in operation and to keep the machine from being started when the cover is open.
24. The rod can be straightened and a piece of close-fitting steel tubing or iron pipe can then be slipped over the rod to increase its stiffness.
25. The pins in as many hinges and clevises as practicable may be upset or riveted.

CHAPTER 10

ENGINEERING CASUALTY CONTROL

1. Preventive maintenance minimizes the occurrence of casualties resulting from material failures.
2. Abnormal operating speeds, temperatures, pressures, noises, and vibrations.
3. All similar units should be inspected to determine whether they may fail for the same reason.
4. Poorly fitted or worn carbon packing.
5. By drawing off settled water and performing a standard chloride test.
6. The commanding officer.
7. The risk of greater damage, or even loss of the ship, if the affected machine is secured.
8. Stop the shaft immediately and simultaneously attempt to regain lubricating-oil pressure.
9. The bearing may be wiped to the extent that the oil passage to the thermometer is closed; or there may be a stoppage of oil to the bearings.
10. The unit should be operated at a low speed until the bearing has cooled; this action keeps the bearing metal from freezing to the shaft.
11. The lubrication system and the purifier should be kept in operation.

12. Through the pinion or shaft misalignment which is permitted when bearings become wiped.
13. Increase the lubricating-oil pressure so that oil will not leak into the waterside of the cooler; pump make-up oil into the sump tank.
14. Plug or patch the leak; inspect the sump oil-level, and strike down purified make-up oil as necessary.
15. The constant-pressure governor may be operating improperly, or there may be restrictions in the lubricating-oil system.
16. Those in the condensate system, the main-feed system, the auxiliary-exhaust steam line, the high-pressure drains, and the fuel-oil heater drains.
17. (1) Sudden loss of deaerating feed tank pressure; (2) stopping or slowing down of main-feed booster pumps; (3) an empty deaerating feed tank; and (4) an insufficient number of main-feed booster pumps in use.
18. By bleeding in make-up steam.
19. The number of pumps in use.
20. Start the main-feed booster pump; start the main-feed pump; and stop the emergency-feed pump.
21. The speed of the pump should be decreased and the pump end should be vented.
22. Those valves which are located where the pump discharge line joins the fire main and the pump discharge valve.
23. Jumpers of hose.
24. By the emergency-steering unit, or with the main engines.

APPENDIX II

QUALIFICATIONS FOR ADVANCEMENT IN RATING

QUALS CURRENT THROUGH CHANGE 10

MACHINIST'S MATES (MM)

General Service Rating

SCOPE

Machinist's mates operate, maintain, and make repairs to ship propulsion and auxiliary equipment such as steam propulsion machinery, shafts, propellers, evaporators, compressors, pumps, valves, oil purifiers, heat exchangers, governors, and reduction gears; maintain and make repairs to outside machinery such as steering engine, anchor windlass, cranes, elevators, food preparation and related utility equipment, and winches; operate, maintain, and repair refrigeration and air conditioning equipment; may perform duties in the generation, stowage, and transfer of the following industrial gases: Oxygen, carbon dioxide, nitrogen, and acetylene.

NOTE.—Personnel in the General Service Rating will not be examined in industrial gas.

Emergency Service Ratings

MACHINIST'S MATES L (General Machinist's Mates) .... MML
Operate, maintain, and make repairs to main propulsion and auxiliary machinery of steam-propelled vessels.

MACHINIST'S MATES R (Refrigeration Mechanics) ..... MMR
Operate, maintain, and repair refrigeration and air conditioning equipment.

MACHINIST'S MATES G (Gas Generating Mechanics) .... MMG
Operate and maintain machinery for generating and compressing industrial gas and for charging compressed-gas containers.

Navy Enlisted Classification Codes

For specific Navy enlisted classification codes included within this rating, see *Manual of Navy Enlisted Classifications,* NavPers 15105 (Revised), codes MM–4200 to MM–4299.

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
100 PRACTICAL FACTORS				
101 OPERATIONAL				
1. Start, operate, stand watch on, and secure double- or triple-effect distilling plants	3	3	------	------
2. Stand watch in steering engine room	3	3	------	------
3. Use radiac instruments and perform monitoring operations on intake lines and evaporators	3	3	------	------
4. Operate a CO_2 plant, refill CO_2 cylinders, and take gas analysis test during operation	----	------	------	3
5. Operate compressors and motors and take gas analysis test on an oxygen plant and log readings on a CO_2 and acetylene plant	----	------	------	3
6. Operate and stand watch on CO_2 and oxygen transfer equipment	----	------	------	3
7. When warming up main steam-propulsion machinery fitted with reduction gear and motor-driven turning gear:				
a. Measure turbine clearances where indicators are installed. Specify that they are cold readings	C	C	------	------
b. Back all throttle valves off seat and reseat lightly by hand	1	1	------	------
c. Check for water in lubricating oil and use lubricating oil purifier if necessary	2	2	------	------
d. Heat lubricating oil in sump tank to 90° F. and secure steam to heating coils	2	2	------	------
e. Clean all oil and bilge strainers	3	3	------	------
f. Ease up on stern tube gland, allowing a small amount of water to leak through the gland	3	3	------	------

Qualifications for Advancement in Rating	MM	MML	MMR	MMG
101 OPERATIONAL—Continued				
g. Line up lubricating oil system	2	2	------	------
h. Start lubricating oil pump	2	2	------	------
i. See that oil is delivered to turbines, reduction gears, and thrust bearings. Inspect for leaks	3	3	------	------
j. Open all drain valves on main steam line	3	3	------	------
k. Test low-pressure lubricating oil alarm system	2	2	------	------
l. Test standby lubricating oil pump	2	2	------	------
m. Obtain permission from bridge and start motor-driven turning gear and jack over main engine	1	1	------	------
n. Open main injection and overboard discharge valves	3	3	------	------
o. Start main circulator pump	2	2	------	------
p. Start main condensate pump and recirculate water	2	2	------	------
q. Cut in gland seal on turbine	2	2	------	------
r. Start second stage air ejector; build up vacuum on main condenser	1	1	------	------
s. Vent main condenser to insure that condenser is not air bound	3	3	------	------
t. Open all auxiliary low-pressure drains to main condenser. Secure auxiliary condenser and cut auxiliary exhaust steam not used elsewhere into main condenser	3	3	------	------
u. Line up system and recirculate water through deaerating tank	1	1	------	------
v. Open drains to whistle and siren	3	3	------	------
w. Cut in steam to whistle and siren	3	3	------	------

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
101 OPERATIONAL—Continued				
x. Warm up main feed pump and booster pump	1	1	------	------
y. Test engine telegraph	1	1	------	------
z. Take and log counter readings	1	1	------	------
aa. Put main feed pumps on line	1	1	------	------
bb. Open bulkhead stops to throttle or nozzle control valves	2	2	------	------
cc. Close throttle bypasses and warming-up valves	1	1	------	------
dd. Obtain permission from bridge and turn main engines	1	1	------	------
ee. Disengage motor-driven turning gear	1	1	------	------
ff. Obtain permission from bridge and spin main engines	1	1	------	------
gg. Take and record hot turbine clearances	C	C	------	------
hh. Start first-stage air ejector; build vacuum to maximum obtainable	1	1	------	------
ii. Line up main lubricating oil cooler	3	3	------	------
jj. Make final inspection preparatory to repo ting engine room ready to answer all bell;	C	C	------	------
8. When securing main steam p opulsion machinery fitted with reduction gears and motor-driven turning gear:				
a. Secure throttle valves	2	2	------	------
b. Rotate turbine rotors with shaft turning gear	1	1	------	------
c. Maintain lubricating oil pressure in all bearings during rotation	2	2	------	------
d. Secure main steam line and drain thoroughly before securing drains	3	3	------	------

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
101 OPERATIONAL—Continued				
e. Open turbine drains	3	3	------	------
f. Secure steam to first-stage air ejectors	1	1	------	------
g. Start auxiliary condenser and cut auxiliary exhaust and low-pressure drains into it	1	1	------	------
h. Start auxiliary and secure main feed pump	1	1	------	------
i. Continue operating turning gear and circulating lubricating oil through the system for at least 1 hour after gland steam has been secured	1	1	------	------
j. Secure steam to second-stage air ejectors	1	1	------	------
k. Secure gland seal steam and condensate pumps	2	2	------	------
l. Complete securing of air ejectors and break vacuum through air ejector suction	1	1	------	------
m. Secure main circulating pumps	2	2	------	------
n. Close main injection and overboard discharge valves	3	3	------	------
o. Inspect to insure that all root, throttle, exhaust, and drain valves of all auxiliaries not in use are closed	2	2	------	------
p. Drain waterside of oil coolers to bilges	3	3	------	------
q. Close turbine and steam line drains after 24 hours	3	3	------	------
9. Start, operate, stand watch on, and secure refrigeration and air conditioning systems	2	------	3	------
10. Start, operate, and secure Diesel generator used for power supply to oxygen plants	----	------	------	2

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
101 OPERATIONAL—Continued				
11. Start, operate, and secure Diesel generator used for an acetylene plant	----	------	------	2
12. Operate engine lathe for cutting threads and tapers and for plain turning	1	1	------	------
13. Start, operate, and secure an oxygen plant	----	------	------	1
14. Select a site and set up industrial gas generating, stowage, and transfer equipment	----	------	------	C
102 MAINTENANCE AND/OR REPAIR	----	------	------	------
1. Change strainers and clean filters on gas generating equipment	----	------	------	3
2. Lubricate all pumps and compressors used in gas generating plants	----	------	------	3
3. Remove scale from evaporator tubes by cold shocking	3	3	------	------
4. Spot and grind in valves	3	3	3	3
5. Renew bonnet gaskets in valves	3	3	3	3
6. Repack stuffing boxes on centrifugal pumps with specified packing	3	3	3	3
7. Replace zinc plates in main and auxiliary condensers	3	3	------	------
8. Clean salt-waterside of main and auxiliary condensers	3	3	3	------
9. Remove drying agent from adsorbers on an oxygen plant and refill	----	------	------	2
10. Repack valves using specified type of packing on gas generating equipment	----	------	------	2
11. Change oil and lubricate Diesel generators used for power supply on gas generating plants	----	------	------	2
12. Make minor repairs to insulation or lagging on piping	2	2	2	2

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
102 MAINTENANCE AND/OR REPAIR—Con.				
13. Remove scale from evaporator tubes chemically	2	2	------	------
14. Fit piston rings to steam cylinder of reciprocating pumps	2	2	------	------
15. Spot-in slide valve on steam chest of reciprocating pump	2	2	------	------
16. Test and renew suction and discharge valves on air compressors	2	2	2	2
17. Use dial indicators, micrometers, depth gages and inside-outside vernier calipers to take clearances on journals and bearings	2	2	2	2
18. Check for noncondensable gases and pump down refrigerant systems	2	------	2	2
19. Use halide torch on refrigeration or air conditioning equipment to test for leaks	2	------	2	2
20. Clean air ejector steam strainers	2	2	------	------
21. Clean inner and after air ejector condenser tubes	2	2	------	------
22. Reface valve seats and discs	2	2	2	2
23. Replace regulating valve diaphragms	2	2	2	2
24. Repack high-pressure valves	2	2	2	2
25. Spot in and replace bearings on centrifugal pumps	2	2	2	2
26. Replace oil seals on refrigeration compressors	1	------	2	2
27. Inspect, dry out, and recondition oxygen and CO_2 cylinders	----	------	------	1
28. Dehydrate, test, and recharge refrigeration systems	1	------	1	1
29. Inspect and recondition acetylene cylinders	----	------	------	1
30. Check alinement of couplings and determine clearances of bearings on pumps for gas generating equipment	----	------	------	1

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
102 MAINTENANCE AND/OR REPAIR—Con.				
31. Set all relief valves to required pressure	1	1	1	1
32. Repair centrifugal pump pressure regulators	1	1	1	1
33. Spot in or replace carbon packing rings on centrifugal pumps	1	1	------	------
34. Take clearances and replace wearing rings on centrifugal pumps	1	1	1	1
35. Check for alinement of centrifugal pump driving unit	1	1	1	1
36. Make air and soapsuds test on main and auxiliary condenser	1	1	------	------
37. Replace worn or broken reciprocating pump piston rings	1	1	------	------
38. Aline upper and lower cylinders of reciprocating pumps	1	1	------	------
39. Adjust slide valve on steam and exhaust side of reciprocating pumps	1	1	------	------
40. Adjust air ejector steam reducing valve	1	1	------	------
41. Adjust air ejector thermostatically controlled recirculating valves	1	1	------	------
42. Adjust tappets for proper piston stroke on reciprocating pumps	1	1	------	------
43. Grind in or replace valve disks and seats in water end of reciprocating pump	1	1	------	------
44. Renew weak or broken valve springs in water end of reciprocating pump	1	1	------	------
45. Remove scores from cylinder wall of water end and steam end of reciprocating pump	1	1	------	------
46. Renew packing rings in water end of reciprocating pump	1	1	------	------
47. Test evaporator tubes hydrostatically for leaks	1	1	------	------

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
102 MAINTENANCE AND/OR REPAIR—Con.				
48. Make repairs to pumps and compressors on gas generating equipment	----	------	------	C
49. Plug and replace condenser tubes	C	C	C	C
50. Set hydraulic speed limiting governor on centrifugal pumps	C	C	------	------
51. Set hydraulic pressure governor on centrifugal pumps	C	C	------	------
52. Set geared centrifugal fly-ball type governor on centrifugal pumps	C	C	------	------
53. Clean first- and second-stage air ejector nozzles and diffusers	C	C	------	------
54. Take main turbine and reduction gear bearing clearances, thrust clearances, and turbine blade clearances	C	C	------	------
103 ADMINISTRATIVE AND/OR CLERICAL				
1. Locate and use appropriate sections of the BuShips Manual, manufacturers' instruction books, mechanical drawings, and handbooks to obtain data when repairing machinery	1	1	1	1
2. Supervise and train personnel in operation, maintenance, and repair of:				
a. All engine room equipment	C	C	------	------
b. Refrigeration and air conditioning equipment	C	------	C	------
c. Gas generating equipment	----	------	------	C
3. Take charge of an engine room watch on steam-propelled vessel	C	C	------	------
4. Take charge of a watch on gas generating equipment	----	------	------	C
5. Keep engine room records and prepare naval shipyard and tender work requests	C	C	C	C

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
103 ADMINISTRATIVE AND/OR CLERICAL Continued				
6. Estimate time and material needed for repair of auxiliary and main propulsion machinery	C	C	-----	-----
200 EXAMINATION SUBJECTS				
201 OPERATIONAL				
1. Safety precautions involved in performing tasks appropriate to applicable rates listed under 100 Practical Factors.				
2. First-aid procedures in instances of exposure to refrigerants in liquid or gaseous states and in instances of electrical shock and heat exhaustion	3	3	3	3
3. Safety precautions to be observed when working on shipboard machinery, taking on fuel, and moving or lifting heavy objects	3	3	3	
4. Safety precautions to be observed when generating, transferring, stowing, and handling industrial gases	-----	-----	-----	3
5. Uses and characteristics of industrial gases and their identification by standard markings on containers	3	3	3	3
6. Purpose and principles of operation of:				
a. Reduction gears	3	3	-----	-----
b. Double- and triple-effect distilling plants	3	3	-----	-----
c. Compressors	3	3	3	3
d. Main and auxiliary condensers	3	3	-----	-----
e. Lubricating oil purifiers	3	3	-----	-----
f. Air ejectors	2	2	-----	-----
g. Rotary, reciprocating, and centrifugal pumps	2	2	2	2

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
201 OPERATIONAL—Continued				
h. High- and low-pressure turbines	2	2	------	------
i. Turning gears	2	2	------	------
j. Steering engines	2	2	------	------
k. Relief valves	2	2	2	2
l. Turbogenerators	2	2	------	------
7. Construction and operation of Freon-12 type of refrigerating units. Characteristics of refrigerants	2	------	3	3
8. Power, fuel, water, chemicals, and other consumable materials required for operation of gas generating plants	----	------	------	2
9. Principles of operation of oxygen, CO_2, and acetylene generating plants and associated equipment	----	------	------	2
10. Tests required by the Interstate Commerce Commission when shipping industrial gas containers	----	------	------	2
11. Purpose and principles of operation of:				
a. Refrigeration expansion valves	1	------	2	2
b. Deaerating tank	1	1	------	------
c. Thrust bearings	1	1	------	------
d. Centrifugal pump governors	1	1	------	------
e. Gland sealing system	1	1	------	------
12. Methods and procedures for starting and securing s'eam turbine generator	1	1	------	------
13. Safety factors to be considered in selection of a site, and in installation of equipment. for oxygen, CO_2, and acetylene generating plants	----	------	------	C
202 MAINTENANCE AND/OR REPAIR				
1. Chloride limits and frequency of tests on the following:				
a. Make-up feed water	3	3	------	------
b. Distiller discharge to reserve feed tanks	3	3	------	------

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
202 MAINTENANCE AND/OR REPAIR—Con.				
c. Main and auxiliary condensers	3	3	------	------
d. Reserve feed tanks	3	3	------	------
e. Deaerating and surge tanks on main feed line	3	3	------	------
2. Purpose and procedures for cold shocking evaporators	3	3	------	------
3. Procedures to be followed when:				
a. Changing and cleaning filters on gas generating equipment	----	------	------	3
b. Lubricating gas generating equipment	----	------	------	3
c. Repacking stuffing boxes on centrifugal pumps	3	3	3	3
d. Replacing zincs in main and auxiliary condensers	3	3	3	3
e. Removing drying agent from adsorbers on oxygen plant	----	------	------	2
f. Removing scale from evaporator tubes	2	2	------	------
g. Fitting piston rings to steam cylinder of reciprocating pumps	2	2	------	------
h. Spotting-in slide valves on steam chest of reciprocating pumps	2	2	------	------
i. Testing and renewing suction and discharge valves on compressors	2	2	2	2
j. Spotting-in and replacing bearings of centrifugal pumps	2	2	2	2
k. Renewing ram packing on hydraulic steering gears and elevators	2	2	------	------
l. Changing seals and gaskets on hydraulic equipment	2	2	------	------
m. Inspecting and adjusting food preparation and dishwashing machinery	2	2	------	------

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
202 MAINTENANCE AND/OR REPAIR—Con.				
n. Inspecting and adjusting safety devices and operating gear on laundry machinery	2	2	------	------
o. Dehydrating, testing, and recharging of refrigeration systems	1	------	2	2
p. Replacing oil seals on refrigeration compressors	1	------	2	2
4. Methods of testing evaporators and condensers for salt water leaks	2	2	2	2
5. Procedures to be followed when these casualties occur:				
a. Leak in condenser	3	3	------	------
b. Deaerating feed tank water level drops during steady steaming	3	3	------	------
c. Deaerating tank too full	3	3	------	------
d. Gage glass on evaporator breaks	3	3	------	------
e. Cooling water to auxiliaries fails	3	3	------	------
f. Jammed throttle (ahead and astern)	3	3	------	------
g. Lubricating oil cooler tube carries away	2	2	------	------
h. Loss of or low lubricating oil pressure	2	2	------	------
i. Lubricating oil leak into engine room	2	2	------	------
j. Excessive lubricating oil pump discharge pressure	2	2	------	------
k. Hot bearings and treatment of overheated bearings	2	2	------	------
l. Empty feed bottom in use for make-up feed	2	2	------	------
m. Casualty to the deaerating feed tank (DFT)	2	2	------	------

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
202 MAINTENANCE AND/OR REPAIR—Con.				
n. Unusual noise from pump end of main feed pump when starting	2	2	------	------
o. Low or loss of main feed booster pump pressure	2	2	------	------
p. Rupture in fuel-oil suction and transfer piping	2	2	------	------
q. Rupture in fire main piping (engineering spaces)	2	2	------	------
r. Rupture in salt water cooling service piping	2	2	------	------
s. Steering gear and propeller casualty—near miss	2	2	------	------
t. Loss of vacuum	1	1	------	------
u. High oil level in the reduction gear case—oil emulsion	1	1	------	------
v. Locking and unlocking of shaft underway	1	1	------	------
w. Shaft vibrates excessively	1	1	------	------
x. Unusual noise in reduction gear	1	1	------	------
y. Metallic noise coming from turbine	1	1	------	------
z. Turbine begins to vibrate	1	1	------	------
aa. Cruising turbine out of commission	1	1	------	------
bb. Rupture in main steam piping (split-plant)	1	1	------	------
cc. Rupture in auxiliary steam piping	1	1	------	------
dd. Rupture in auxiliary exhaust piping	1	1	------	------
ee Rupture in main feed piping	1	1	------	------
ff. Rupture in high pressure drain piping	1	1	------	------
gg. Rupture in fuel oil heating drain piping	1	1	------	------

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
202 MAINTENANCE AND/OR REPAIR—Con.				
hh. Loss of steam pressure in engine room	1	1	------	------
ii. Main turbine casualty—near miss	1	1	------	------
jj. Fire room explosion—torpedo hit	1	1	------	------
kk. Engine room explosion—shell hit	1	1	------	------
ll. Engine room explosion—torpedo hit	1	1	------	------
6. Lubricant requirements and precautions when handling dehydrated oils for refrigerant systems	1	------	2	2
7. Methods of fitting carbon packing rings to turbines	2	2	------	------
8. Procedures to be followed when:				
a. Inspecting and reconditioning oxygen, CO_2, and acetylene cylinders	----	------	------	1
b. Checking alinement of couplings and determining clearances of bearings on pumps for gas generating equipment	----	------	------	1
c. Setting relief valves	1	1	1	1
d. Repairing centrifugal pump pressure regulators	1	1	1	1
e. Taking clearances and replacing wearing rings on centrifugal pumps	1	1	1	1
f. Checking alinement of centrifugal-pump driving unit	1	1	------	------
g. Replacing worn and broken reciprocating-pump piston rings	1	1	------	------
h. Adjusting tappets on slide gear of reciprocating pumps	1	1	------	------
i. Adjusting steam reducing valves	1	1	------	------
j. Cleaning first- and second-stage air ejector nozzles and diffusers	C	C	------	------

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
202 MAINTENANCE AND/OR REPAIR				
k. Replacing turbine or reduction gear bearings	1	1	------	------
9. Methods of testing oxygen, CO_2, and acetylene gas generating systems and equipment for proper operation	----	------	------	1
10. Methods of testing refrigerating systems, including compressors, for proper operation	1	------	1	1
11. Factors governing main propulsion plant efficiency, causes of poor performance, and appropriate remedies	C	C	------	------
12. Major causes of inefficient operation of refrigerating systems and corrective procedures	C	------	C	C
13. Procedures for checking and adjusting constant-speed and speed-limiting governors and overspeed trips	C	C	------	------
14. Methods of taking main turbine and reduction gear bearing clearances, thrust clearances, and turbine blade clearances	C	C	------	------
15. Procedures to be followed when inspecting propellers, shafts, sea valves, zincs, and strut and stern tube bearings when ship is in drydock	C	C	------	------
16. Characteristics of lubricating oil and purpose of tests	C	C	C	C
17. Procedures to be followed when replacing rotors in main feed, main feed booster, main condensate, and main lubricating oil pumps	C	C	------	------

Qualifications for Advancement in Rating	Applicable Rates			
	MM	MML	MMR	MMG
202 MAINTENANCE AND/OR REPAIR—Con.				
18. Procedures for replacing thrust plates in main turbine thrust and turbogenerator thrust bearings and thrust shoes in Kingsbury thrust bearings	C	C	-----	-----
203 ADMINISTRATIVE AND/OR CLERICAL				
1. Duties and responsibilities of the engineer officer of the watch	C	C	C	C
2. Performance reports required by Bureau of Ships and Chief of Naval Operations and purpose of all records kept by engine room personnel	C	C	C	C
3. Selection, procurement, and use of packings, grease, oils, polishes, cleaning materials, spare parts, and other engine room supplies	C	C	C	C
4. Use of allowance lists, and procedures for maintaining inventories and obtaining replacements	C	C	C	C
5. Application of damage control principles	C	C	C	C
6. Knowledge of administrative, material, and operational readiness inspections	C	C	C	C
7. Supervise and make out reports for full power, economy, dock, and post-repair trials	C	C	-----	-----
300 PATH OF ADVANCEMENT TO WARRANT OFFICER AND LIMITED DUTY OFFICER				
Machinist's Mates advance to Warrant Machinist and/or to Limited Duty Officer, Engineering.				

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